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SOUND STEEL FOR RAILS AND STRUCTURAL PURPOSES.*

BY

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WITH reference to the recent interesting paper by Dr. Allerton S. Cushman on "Research in Metallurgy of Iron," which appeared in the July JOURNAL, and its reference to sound steel, the writer desires to put the following statements before The Franklin Institute, as a contribution on this important question of producing steel which can be safely used for railroad track work and structural requirements generally.

The various papers by the writer on this subject are shown in Table III at the end of the paper. These are given as reference for those who may wish to further investigate this matter.

As rightly pointed out in Dr. Cushman's valuable paper, the question of sound steel is of the utmost importance, covering, as this does, the production of sound rails. The rail problem in America is a serious one and concerns the safety of the travelling public, yet rails continue to be produced from ingots made in practically the same manner as used for years back; in fact, ingot-making practice is pretty much the same to-day as it was ten years ago. This is the more to be regretted when simple, cheap,

* Communicated by the Author.

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and efficacious methods are in existence by which the trouble and dangers now met with can be overcome. In other words, there is not the slightest necessity that unsound material should be produced for rail or other purposes; in fact, strange as it may seem, there is also no reason why a single unsound ingot need be produced. This is shown by the following research work which the writer has carried out during the last few years.

Photograph No. 2074 (Plate I) represents two 18-inch ingots made by the writer's system, weighing about 2¾ tons each. These ingots were cast with the small end up, as in ordinary practice. This photograph is interesting, as it gives an excellent view of the cavity produced by the sound steel in these ingots as it settles down into the body of the ingot proper; that is, below the feeding head. As previously mentioned, in these ingots it is not necessary, in order to determine whether they are sound or not, that machining or other observation by mechanical methods should be carried out, and at least 88 per cent. to 90 per cent. of sound usable and salable material is obtained. This, too, can be accomplished just as readily and easily with 10,000 or 100,000 as with one ingot.

If the reader will examine photograph No. 2065 (Plate II), which shows an ingot made in the present and ordinary manner, he will see that not even the most experienced expert could say whether the interior of the ingot was sound or unsound, whereas the ingot in photograph No. 2074 (Plate I) shows the steel to have settled or sunk down. When steel so sinks it is a definite proof that the material is sound and free from blowholes. In other words, the presence of this cavity is conclusive evidence of the soundness of the steel. If the steel were not sound there would be no cavity, so that this particular quality of soundness of the steel is made self-apparent.

The following results further illustrate this important advance in the production of sound steel:

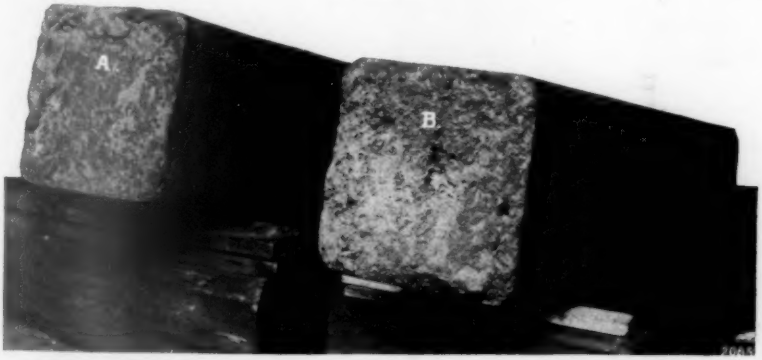
To show how considerable is the cavity which forms in piping steel, nine 15-inch ingots were taken (weighing about 3600 pounds each) as they came through, each of which had the sand head and the writer's improved method of feeding carried out on them. After the ingots had cooled down, the hollows or cavities in the sand heads were filled with water, then the water poured out and carefully measured. Table I shows the results obtained.

PLATE I.

18-INCH INGOTS, WEIGHING ABOUT 2¾ TONS. THESE INGOTS WERE MADE BY THE HADFIELD PATENTED METHOD FOR PRODUCING SOUND INGOTS.

Photograph No. 2074.

PLATE II.



18-INCH INGOTS, WEIGHING ABOUT 2¼ TONS. INGOT A, UNSOUND INGOT. INGOT B, PIPED INGOT.

Photograph No. 2065.

TABLE I.

Ingot number	Cubic inches	Pounds of steel	Percentage of weight of ingot
1	457	128	3.57
2	549	154	4.30
3	457	138	3.57
4	457	128	3.57
5	472	132	3.68
6	488	137	3.82
7	518	145	4.05
8	579	162	4.52
9	488	137	3.82
Average	496	139	3.88
Maximum	579	162	4.52
Minimum	457	128	3.57

Weight of Ingot, 3600 pounds.

The average weight for the nine 15-inch ingots showed that 139 pounds, with a minimum of 128 pounds and a maximum of 162 pounds, passed from the head portion into the ingot itself. This percentage is represented by an average figure of 3.88 per cent. In other words, about 4 per cent., or 140 pounds, of the total weight of the ingot or ingots cast passed from the upper or feeding head into the body of the ingot.

There could not be a more striking illustration of the quality of the ingots produced and of the value of this system. Even in the case of the minimum percentage weight of steel which passed from the head of the ingot itself, there is a weight of no less than 128 pounds of steel short in the head, and therefore present in the ingot itself, all adding to the soundness and proper feeding of the piping which would otherwise occur.

To show still more clearly the important information obtained from these experiments, let it be assumed that the cubic capacity of each of the 15-inch ingots in question was approximately 12,500 cubic inches. Therefore, but for this feeding, there would be a general want of solidity, chiefly at the upper portion of the ingot, to the extent of, say, 500 cubic inches—say, 4 per cent.—of the whole capacity. It is surely readily apparent why an ingot which is not fed must perforce be deficient in homogeneity.

It is not claimed that ingots made in the ordinary manner are deficient to the full extent of, say, 4 per cent., even when the steel is sound, which, unfortunately, is usually not the case. There

is a certain amount of feeding effect from the steel in the upper portion of the ingot, but this is not done efficiently, as the steel quickly freezes on the outside of the mould and on the surface of the liquid steel exposed to the air. Moreover, there is always an uncertainty as to how good or how bad is the resulting material. If the steel is piping very much, the trouble will be worse than when it is piping less. In any case, as the steel solidifies in an ingot of this size, the natural law of contraction demands that about 500 cubic inches have to be dealt with; that is, on an ingot of the weight and size mentioned. The writer cannot see how this can be efficiently and cheaply met except by some such method as described in this paper.

While the results necessarily vary slightly, because the sizes of the head portion nearest the top of the mould formed in sand are not always uniform in length, as the steel shrinks down slightly more on the outside in some cases than others, on the whole the maximum and minimum figures of 4½ and 3½ per cent. of the total weight of the ingot having passed from the head into the ingot itself show very uniform working; if the heads were absolutely the same depth in each case, there would be practically no difference.

Without wishing to exaggerate, it is easy to picture to oneself what would be the character of each of these ingots, if not made and treated under the method now described. The piping would have probably run down the ingot itself, requiring a discard of probably 25 to 33 per cent.

Although water cannot be poured into the cavity of a red-hot ingot, yet the cavity can be determined in each ingot by a cursory examination while at a red or yellow heat, involving only a few seconds of time. It will, therefore, be seen that every ingot can be readily checked by such cursory examination.

While in ingots made in the ordinary way as above mentioned a certain amount of the fluid steel passes from the upper portion to the lower, still in so doing it is robbing the quality of the upper portion of the ingot itself, which has no fluid metal above it to feed or take the place and supply the deficiency thus created. It will readily be understood, therefore, why the upper portion of ingots is so seriously affected as regards their soundness, also why segregation occurs. This is shown in a remarkably clear manner by Fig. B in Plate IV, showing an ingot made in the

ordinary manner in America and afterwards cut up by the Standards Bureau. The occurrence of these defects varies according to the type of steel, whether rising, semi-rising, or settling nature.

Again referring to this question of the cavities, if, as proved by these experiments, in the ingots made under the writer's system the metal in the sand head portion in descending has without doubt felled or prevented the formation of what would otherwise have been unsoundness, piping, loose structure, or segregated material. In unfed ingots made in the ordinary way there must be steel of loose structure; if not, then in many cases absolute unsoundness and segregation.

Moreover—and this is a most important point—the steel in the "fed" ingots, being maintained fluid in the head portion, continues to exert its ferrostatic pressure, whereas with ingots made in the ordinary way the ferrostatic pressure on the centre portion of the ingot is so slight that it produces very little beneficial effect. Further, without the feeding head above the ingot proper, the outside of the ingot in the ordinary ingot mould becomes rapidly chilled and frozen, so that it cannot contribute its proper share to the feeding of the remaining portion of the ingot. It is not, therefore, to be wondered at that rails rolled from the A and B portions of an ingot made in the ordinary way are liable to unsoundness or piping, or both, and are also often full of impure segregated material.

There would probably be more dangerous ingots but for the fact that the steel maker tries to avoid this type of steel, and aims to make steel which when poured into the ingot will not pipe. Nevertheless, he is still fighting against a natural law. If piping steel is checked or avoided, he runs the risk of producing unsound steel, especially in the upper portion of the ingot, more or less permeated with blowholes. Thus, owing to lack of feeding from the upper portion, the centre, or that portion on the axis line of the ingot, must be of inferior nature, as the piping characteristics persist for quite a long way down the ingot. This, as before mentioned, is for the reason that, owing to want of ferrostatic pressure, the ingot lacks feeding from above, which, in the system of casting ingots now described, is maintained to a very late stage: that is, until or close upon actual solidification takes place. There is always fluid steel in the upper portion of the ingot to feed the

piping and shrinkage, both of which must occur, as they follow a natural law. This, too, is the reason why there is so little segregation in ingots made under the writer's system, and also explains why the ferrostatic pressure is kept up to a very late stage. In fact, check or hinder ferrostatic pressure, and segregation, with its bad effects, at once commences. In the case of "fed" ingots, the smaller amount of segregation which occurs takes place outside the ingot proper; that is, in the head.

With steel of piping nature poured into the ingot moulds and not fed, it need cause no astonishment to find that rails, even from C and D portions of the ingots, may be of material with loose structure, consequently weak, if not actually unsound, thus giving inferior or bad results in service. With piping steel not properly fed, there is extreme danger of this pipe extending a long way down the ingot; in fact, in some cases it has been found to go as much as two-thirds the length of the ingot. Ingots have also been found in which the piping has apparently stopped, only to be resumed below the sounder steel.

The experiment carried out by the writer some years ago, by the pouring of copper into the upper portion of an ingot 15 or 20 minutes after casting, showed how serious is this want of ferrostatic pressure in the material situated on or near the centre or axis line of the ingot in ingots which have not been properly fed. The copper finds its way down to the bottom of the ingot, although added 15 minutes after casting. This is illustrated by Plate III. In any case, if there is no definite pipe at the bottom portion of such ingot, there is still material of loose or open structure, which means weak steel. Although this may not be apparent by fracture to the naked eye, nevertheless it exists, and can generally be detected by an examination of the microstructure. In other words, notwithstanding that the product to be used may come from the lower half of the ingot, yet in unfed ingots it will be weak and not able to stand severe stresses. This is probably the real explanation of the serious breakages which sometimes occur in even C and D rails. Imperfect material is present; only time and sufficient working stresses are wanted to develop its existence and weakness.

It is true that some portions of the cavities in ingots have been measured, but probably not in the manner described by the writer.

Although in the examination of the top of an ingot cast in

the ordinary manner and from steel which "settles" there is external evidence of some piping, this is irregular and varies considerably. Therefore, in the "best" ordinary ingot proper evidence is slight as to how much or how little the steel has piped. Dr. Dudley has pointed out, in his interesting paper to the Institute on "Piping and Segregation of Ingots of Steel and Duc-

PLATE III.

tility-tests for Open-hearth Steel Rails," read in February, 1913, that in such ingots the piping is divided into two kinds: the upper, or what may be termed the visible pipe, and the lower, or hidden pipe, the extent and character of which can be determined only by cutting open the ingot. In the ingots cast under the writer's system, *all the cavity or pipe is open* and can readily be inspected from the top; its extent can be determined whether in the hot or

cold condition. It is, therefore, not necessary to cut open the ingot. In other words, such cavity produced by the piping is "the outward and visible sign of an inward and spiritual grace" —"spiritual grace" in this case meaning "soundness."

PLATE IV.

FIG. A

INGOT MADE BY THE HADFIELD SYSTEM. PERFECTLY SOUND, FREE FROM BLOWHOLES PIPING, AND SEGREGATION.

FIG. B

INGOT MADE IN ORDINARY MANNER. UNSOUND, WITH BLOWHOLES, PIPING, AND SEGREGATION.

Photograph No. 2221

Dr. G. K. Burgess, of the Bureau of Standards, Washington, is at present working with the writer on a joint research relating to this subject, and, though the full details of the work done cannot at the present time be given, it may be stated that ingots

made under the writer's system were carefully cut up by the Bureau and compared with similar ingots produced at rail mills and made in the ordinary manner. The comparisons are shown by the enclosed photograph No. 2221 (Plate IV), in which Fig. A represents the ingot made under the writer's system, as described in the various papers, and Fig. B represents an average ingot made by one of the rail makers. It will be seen there is a remarkable difference in favor of ingots made under the writer's system. It is apparent that thoroughly satisfactory rails cannot be produced from ingots of the B type, representing ordinary ingots produced by the rail maker. In the writer's ingot, Fig. A, there are no blowholes and no segregation below the head portion. The ordinary ingot, Fig. B, is very unsound, badly piped, and is segregated through nearly half its total length.

While the average ingot used for rail manufacture is known to be imperfect, it is difficult to realize such ingots are so decidedly inferior as shown by Fig. B, but such is the case. This, it must be remembered, represents the results of an independent examination by no less an authority than the Bureau of Standards. The full report of this research will be shortly issued by the authors, namely, Dr. G. K. Burgess and the writer. It may be mentioned that this entirely confirms the great advantages to be obtained in ingots made by the system referred to in this paper. Moreover, the same authority states that rails rolled from ingots made under the writer's system show that the metal is quite sound, clear up to the front end of the first rail rolled (that is, immediately under the feeding head), whereas from the B ingot made in the ordinary manner, of which hundreds of thousands are turned out annually, at least two or three of the rails obtained are unsound and piped. It is doubtful whether there would be remaining even 40 per cent. of perfectly sound material, as against about 88 to 90 per cent. in ingots made under the writer's system.

A further exceedingly important advantage possessed by the writer's system is that it is possible to know definitely that *every ingot* made is good or bad *before it goes to the rail mill.* This is entirely a new feature, for, as ingots for rails are now made, they all look alike. An expert, if challenged to indicate by an outward examination of the ingots what would be the quality of the rails from the ingots as now made—for example, those shown in photograph No. 2065 (Plate II)—would be completely at a

loss to express any opinion; it is not possible to see " into " (that is, inside) the ingot. On the other hand, with ingots made under the writer's system the soundness of every one can be determined by superficial examination, either when hot or cold, requiring only a few seconds. In other words, before the ingot goes to the rail mill it can be known whether the steel in the ingot itself is sound or not. If the hollow cavity is present, the material below in the ingot proper will be perfectly sound and free from honeycombs, blowholes, segregation, or piping. This cannot be determined in ordinary ingots; that is, it is impossible to ascertain by a superficial examination whether they are sound or unsound, or to determine the nature of the unsoundness or piping present in them. The only way to make such determination would be to have each ingot sliced up by machining, and thus spoiled for actual work, before it could be decided whether the rail or other article produced from the ingot would be sound.

It is, therefore, difficult to understand why there is so much apathy in America with regard to this important matter, especially when the definite statement is made that it is possible to *check every ingot* and to know whether it is right or wrong, and whether safe for being used in the production of rails. As this is the case, it will be seen that the sound rail problem has been practically solved. Certainly no more accidents need occur owing to rails having imperfections due to unsoundness, blowholes, or segregation. It will be understood how important this is, for it means that breakages from these causes would entirely cease.

It is true that even a sound rail will sometimes break, but such cases are few. Moreover, some of the so-called mysterious breakages have really occurred in parts of rails which, while they have appeared to be sound, upon proper examination have been found to be microscopically unsound. In ingots made under the system now referred to, the material is free from this unsoundness. Segregation is entirely avoided; therefore, the whole of the material used is free from those internal defects produced by the piping and segregation found in ingots made in the ordinary way.

It will be seen, on looking at Fig. B in photograph No. 2221 (Plate IV), representing the average ingot now used, that it is not common sense to expect a rail produced from such an ingot to be sound. In rolling, the defects noticed may be closed up to

some extent, but the final product must be of inferior strength. Compare this unsound ingot, Fig. B, with the sound ingot, Fig. A, when the above will be at once apparent.

To prove that unsound steel will not give the best test, even after being rolled and forged, a short time ago the following tests were made by the writer. The results now given are published for the first time. It will be seen that very important conclusions are arrived at by means of these experiments. The tests quoted were obtained under the following conditions.

The object aimed at was to see whether forged bars, rolled rails, or other worked forms, obtained from unsound ingots, give as good results as from sound ingots. It has been claimed that steel which is unsound in the ingot will, after being forged, show equal mechanical strength to that from sound ingots. The writer has long believed that this prevalent idea was probably not correct, and the results of the following tests show that there is considerable difference, as might be expected, as compared with unsound steel.

The experiments were carried out in the following manner: Three ingots of the same composition were selected, namely—

C	Si	Mn
0.87 per cent.	0.17 per cent.	0.78 per cent.

Ingot *A* (No. 3123C–1) To this aluminum was added. The ingot was provided with the feeding head described in this paper and was sound.

Ingot *B* (No. 3123C–2) To this aluminum was added. While the steel in this ingot was sound, it was not provided with the feeding head and was, therefore, piped.

Ingot *C* (No. 3123C–3) To this no aluminum was added. The ingot was unsound.

A portion of each of the ingots was forged into bars 1¼ inches square, and the usual mechanical tests were taken as shown in Table II.

In each case the mechanical tests from the unsound ingot were found to be considerably inferior. For example, test bar No. 7791F from the sound steel showed an elongation of 8 to 9 per cent., whereas the same steel made from the unsound ingot, and notwithstanding that it was forged, thus apparently closing up the blowholes, showed only 3½ per cent. elongation. The shock tests also confirm the superiority of the sound steel. It is, therefore, quite clear that rails, bars, or other products from sound

TABLE II.

MECHANICAL TESTS ON

(*A*) Sound ingots made under the Hadfield system.
(*B*) Piped ingots of similar type and nature to those at present made in rail mills.
(*C*) Unsound ingots; that is, blowholes, to which no aluminum was added.
The tests were carried out on forged bars 1¼ inches square.

Test No.	Ingot No.	Analysis			Type of ingot	Top or bottom	Tensile tests				Shock tests from specimen taken								Ball tests	
											(*A*) Longitudinally				(*B*) Transversely					
											Fremont nick		"No" nick		Fremont nick		"No" nick			
		C	Si	Mn			Yield point	Maximum stress	Elongation	Reduction in area	Kgm.	Bending angle	Kgm.	Bending angle	Kgm.	Bending angle	Kgm.	Bending angle	Longitudinally	Transversely
									p. ct.	*p. ct.*										
7791F	*A* (3123C–1)	.87	.17	.78	Sound...	Top....	33	64	8½	14	1.2	2½	10	12	0.9	1	2	2	280	272
7792F	*B* (3123C–2)	.87	.17	.78	Piped...	Top....	32	60	9	10	0.4	1½	11	18	1.2	1	3	2	276	274
7793F	*C* (3123C–3)	.86	.12	.79	Unsound.	Top....	38	62	3½	3½	0.4	1	11	16	0.9	1½	3	1	280	283
7794F	*A* (3123C–1)	.87	.17	.78	Sound...	Bottom	35	65	10½	14	1.5	2	11	17	1.0	1½	10	13	274	269
7795F	*B* (3123C–2)	.87	.17	.78	Piped...	Bottom	37	65	9½	13½	1.5	2	13	19	1.5	1	10	12	274	277
7796F	*C* (3123C–3)	.86	.12	.79	Unsound.	Bottom	34	56	2½	3½	0.4	2	4	2	0.6	½	5	5	283	283

The material from *B* ingots being sound (that is, of the settling type), naturally shows good mechanical tests, but it is quite as dangerous as that from type *C*, because the pipe runs very far down the ingot. Very serious and dangerous defects often, therefore, exist, as the shrinkage or cooling of the steel is not properly fed.

Ingots of type *A* made under the Hadfield system show the best results in mechanical tests. Moreover, every portion of the ingot is of exactly the same character; there is no unsoundness, nor is there any piping. Ingots of the unsound blowhole type are not only bad in their unsoundness, but the rails produced from them are mechanically weak, as shown by the tensile tests.

steel are much safer and better in every way than when produced from ingots which were originally unsound.

While it is true that in unsound steel of very mild character the process of forging or rolling closes up the blowholes, and probably, if the heating temperature for rolling or forging is hot enough, the blowholes are welded together, but even then it is doubtful whether such material can ever afterwards possess exactly the same tenacity and ductility as the same steel worked up from a sound ingot. In the case, however, of rail steel in which the carbon percentage is high, the same amount of welding does not take place; in fact, it is doubtful whether the blowholes are more than merely pressed together; consequently the work cannot be so strong as regards tenacity or ductility.

As an addition to the present paper, and showing the efficiency of this method of making sound ingots, with its consequent advantages of the three important factors—(*a*) sounder material, free from piping and segregation; (*b*) better mechanical tests, including tensile and shock tests, (*c*) cheaper production—the writer also adds the results of further investigations completed only a few weeks ago. It is hoped they will prove to be of considerable scientific and practical value, entirely confirming, as they do, the conclusion arrived at with regard to the advantages of this system of making sound steel for ingots to be used in producing rails and other articles.

As large quantities of high explosive steel shell are used by various governments, it is most necessary to obtain steel of the highest quality and yet at not too high cost. In other words, there is required steel of superior quality to that ordinarily used for rails, ship and boiler plates, angles, bars, etc. The system of manufacturing ingots of sound steel described in the present paper exactly meets these special requirements. Moreover, it can be used for making the comparatively lower quality steel referred to; that is, lower quality of material as now made, owing to unsoundness, piping, and presence of segregation.

Several important governments, after making exhaustive tests, have been so satisfied with the Hadfield system of making sound ingots that, both for their land and sea services, they have now authorized explosive shell being made from ingots (afterwards forged into necessary billets) produced in the manner described in this paper.

As will be understood, an explosive shell, whether of small or large calibre, must be absolutely safe; that is, it must be (*a*) sound (that is, free from blowholes); (*b*) free from pipes; (*c*) free from segregation. Any flaw in the shell leading to its premature bursting would be most disastrous. In order to be absolutely certain of obtaining this combination of desirable qualities, it has, in the past, for ingots made in the ordinary manner, been insisted upon by the user concerned that something like 40 per cent. to 50 per cent. of the ingot—in fact, sometimes more than this—must be discarded or wasted; that is to say, only about 60 per cent of

TABLE III.

BIBLIOGRAPHY.

Papers by the Author.

Title	Name of institute where research was read, or press reference	Year of publication
"Experiences sur la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1910
"The Production of Sound Steel"	*Iron Age*	1912
"On a New Method of Revealing Segregation in Steel Ingots"	Iron and Steel Institute	1912
"Method of Producing Sound Ingots"	Iron and Steel Institute	1912
"Plant for Hadfield Method of Producing Sound Steel Ingots"	American Institute of Mining Engineers	1913
"Methode pour Produire des Lingots d'Acier sains et Deceler la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1913
"Nouvelle Methode pour Deceler la Segregation dans les Lingots d'Acier"	*Revue de Metallurgie*	1913
"Sound Ingots"	American Institute of Mining Engineers	1914

the total weight of the ingot was permitted to be used. Ingots made by the writer's method, however, are now allowed after discarding only 15 per cent. It would also be quite possible under the system to give perfectly safe shell with only 10 per cent. to 12 per cent. discard, and to ensure the qualities under the headings (*a*), (*b*), and (*c*) just referred to. This means a reduction in discard from 40 per cent. to 15 per cent. This decision has been arrived at after carefully cutting up and examining over one hundred ingots made by the Hadfield system; that is, not made specially, but produced in the ordinary course of working. Each of these ingots, on being cut up, was found to be perfectly sound,

free from piping and segregation, and thus thoroughly suitable for the difficult class of projectile work mentioned.

In view of the peculiar nature of the purpose to which the steel now referred to has to be put (that is, for explosive shell), it is satisfactory to find that the discard hitherto necessary can be so greatly reduced, namely, to from only 10 per cent. to 15 per cent. of the total weight of the ingot, and yet at the same time the highest quality of material produced.

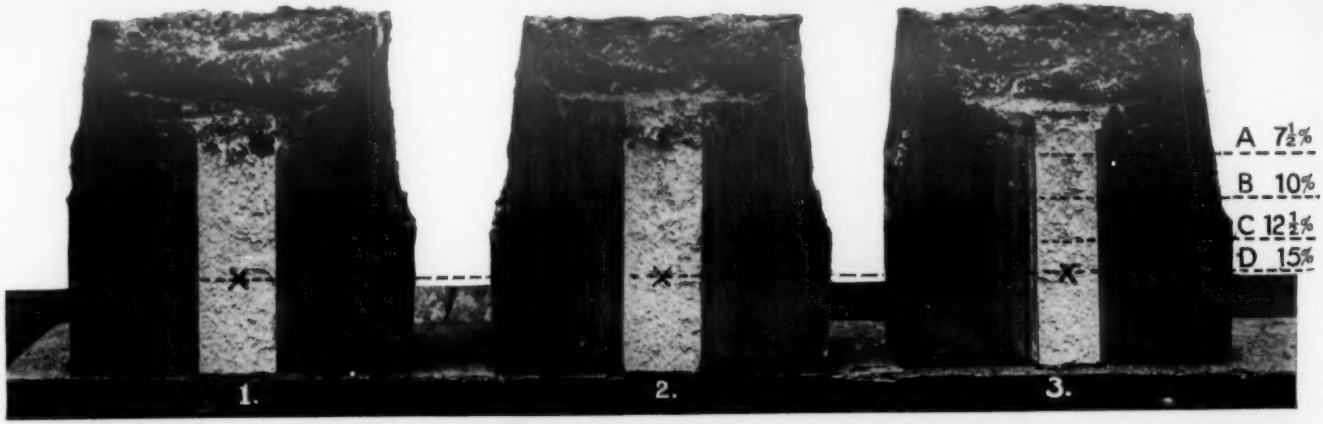
It should be remembered that steel produced from the ingots to be used for the requirements of various governments is most critically examined by many inspectors supervising the material produced and the work done, not on the ingot only, but on each projectile, also including a considerable number of mechanical tests from each ingot, and from a certain number of projectiles made from each ingot. Moreover, each individual ingot is cut up and has to be passed on its own discard; if this were not satisfactory the ingot would be rejected. As pointed out, before the Hadfield system was accepted, more than one hundred ingots were examined in the most severe manner, being cut up from top to bottom. *Every one was found to be satisfactory.*

The following demonstration was made to show the importance and efficiency of the system:

Plate V (photograph No. 2273) shows the upper portion of three 15-inch ingots made under the Hadfield system. This plate shows the soundness and freedom from piping of the ingots. If this is compared with the section of the ordinary rail ingot shown in Plate IV (photograph No. 2221), Fig. B, representing average and current practice, it will be seen how great is the difference. While sound material, whether rails or other articles, can be expected from ingots made as shown in Plate V (photograph No. 2273), it can be well understood that if steel for explosive shell were made from an ordinary steel ingot cast in the usual manner, as shown in Plate IV (Fig. B), there would have to be at least 50 per cent. discard in the ingot, and even then it is doubtful if the material could be safely used.

It must be borne in mind that probably nine-tenths of the ingots used throughout the world, whether for blooms, billets, rails, plates, bars, or other purposes, are made by what is termed "the ordinary method," the result often being not only imperfect but dangerous material.

PLATE V.



The following is the analysis of the material, taken from the ordinary small sample or test ingot:

C	Si	S	P	Mn
.38	.19	.036	.031	.96 per cent.

The following is the analysis on the centre or axis line, as shown by the cross; that is, at the parting line where the 15 per cent. discard was taken:

C	Si	S	P	Mn
.39	.19	.033	.031	.96 per cent.

Similar analyses were also obtained from the 12½ per cent. and 10 per cent. discard lines. It was only when the 7½ per cent. discard line was reached (that is, within one or two inches of the top of the ingot) that the analysis showed any change, namely, as follows:

C	Si	S	P	Mn
.54	.19	.056	.031	.96 per cent.

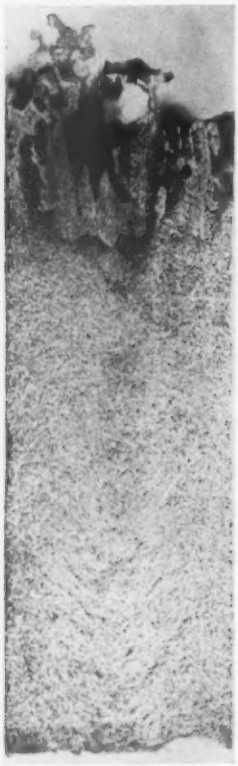
After cutting off 10 per cent. discard from the ingot, the whole of the remaining material is: (*a*) absolutely sound; (*b*) free from blowholes; (*c*) free from segregation.

That portion of the ingot above the transverse section line *A* represents 7½ per cent. discard; *B* represents 10 per cent. discard; *C* represents 12½ per cent. discard; *D* represent 15 per cent. discard.

Photograph No. 2273

To further prove this, Plate VI (photograph No. L.4640) shows an etching of the fractured portion of a 15-inch ingot, marked No. 3 in Plate V (photograph No. 2273) on the centre or axis line, where segregation is usually met with to the greatest extent. This being so sound and free from segregation, it was necessary to continue the etching beyond the fractured portion.

PLATE VI.



Photograph No. L. 4640

The analysis of this particular 15-inch ingot is shown in Table IV. From this table it will be seen that there are no signs of segregation, unsoundness, or piping of any kind until the extraordinarily small discard of 7½ per cent. has been reached. Even in this case the difference in composition is very slight, whereas the

composition of an ingot made in the ordinary manner and with only 7½ per cent. discard, to say nothing of the unsoundness, would show probably 0.60 to 0.70 per cent. carbon and 0.07 per cent. each of sulphur and phosphorus.

TABLE IV.

ANALYSIS OF THE 15-INCH INGOT, NO. 3, SHOWN IN PLATE V.

	Analysis				
	C	Si	S	P	Mn
Original steel	.36	.19	.031	.031	.96
A. Discard of 7½ per cent. (sand or feeding head of ingot)	.54	...	.056	.031	...
B. Discard of 10 per cent	.46	...	.040	.031	...
C. Discard of 12½ per cent	.39	...	.040	.031	...
D. Discard of 15 per cent	.39	...	.033	.031	...
E. Bottom of ingot	.38	.19	.031	.031	.96

TABLE V.

SHOWING COMPOSITION OF THE STEEL MADE BY THE SOUND STEEL SYSTEM DESCRIBED IN THIS PAPER.

Table A represents the analyses of drillings from the usual ladle ingot tests

Table B represents the analyses of the same steel, carried out by an independent inspector.

The drillings were taken from the centre or axis line of each ingot, exactly on the parting line of the 15 per cent. discard.

Mark	TABLE A					TABLE B				
	Analyses made by Hadfield of drillings from the usual ladle ingot tests					Analyses made by the inspector from drillings taken from the *centre or axis line* of each ingot after cutting off 15 per cent. discard				
	C	Si	S	P	Mn	C	Si	S	P	Mn
1229	.40	.22	.030	.033	.89	.37	.24	.031	.035	.87
1231	.38	.21	.031	.037	.88	.40	.21	.029	.036	.88
1233	.40	.21	.033	.035	.90	.39	.20	.035	.036	.88
1234	.39	.21	.032	.033	.89	.39	.21	.036	.038	.90
1243	.40	.26	.034	.029	.91	.39	.23	.026	.034	.88
1244	.38	.23	.031	.032	.93	.43	.22	.038	.034	.86
1245	.39	.25	.030	.030	.99	.38	.24	.030	.032	.91
1246	.40	.21	.029	.029	.95	.39	.19	.025	.030	.87
1247	.37	.19	.030	.032	.89	.39	.18	.025	.033	.86
1248	.41	.20	.026	.036	.87	.45	.20	.027	.029	.81

Table V shows a number of analyses taken during the ordinary course of working (that is, they are not in any way special) from the centres of different ingots as above described, the drillings for

analysis being taken exactly at the parting line where the 15 per cent. discard has been made. The figures obtained clearly show the important fact that the steel is as pure and free from segregation at this part as it is at the bottom or at any other portion of the ingot.

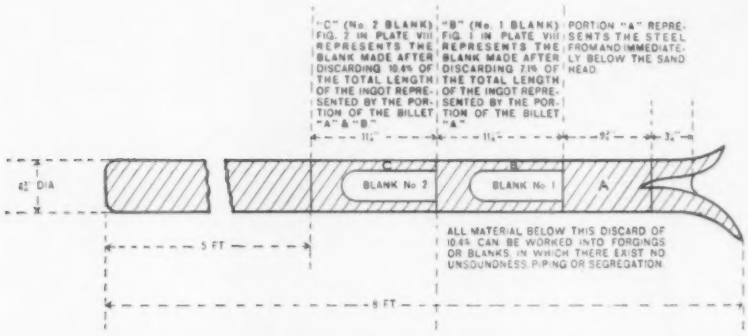
As a further test, the following interesting experiment was made:

The portion of one of the ingots representing the usual 40 per cent. of the discard hitherto demanded in the manufacture of high explosive shell was taken from an 11-inch ingot having the following analysis:

C	Si	S	P	Mn
.38	.18	.024	.035	.85 per cent.

This was forged into a bar 4¾ inches in diameter and about 8 feet in length, as shown by Fig. 7. Projectiles were forged from this bar as follows:

FIG. 7


"C" (No. 2 BLANK) FIG. 2 IN PLATE VIII REPRESENTS THE BLANK MADE AFTER DISCARDING 10.4% OF THE TOTAL LENGTH OF THE INGOT REPRESENTED BY THE PORTION OF THE BILLET "A" & "B"
"B" (No. 1 BLANK) FIG. 1 IN PLATE VIII REPRESENTS THE BLANK MADE AFTER DISCARDING 7.1% OF THE TOTAL LENGTH OF THE INGOT REPRESENTED BY THE PORTION OF THE BILLET "A"
PORTION "A" REPRESENTS THE STEEL FROM AND IMMEDIATELY BELOW THE SAND HEAD.
11½"
11½"
9½"
3½"
4¾" DIA
C
BLANK No 2
B
BLANK No 1
A
5 FT
8 FT
ALL MATERIAL BELOW THIS DISCARD OF 10.4% CAN BE WORKED INTO FORGINGS OR BLANKS, IN WHICH THERE EXIST NO UNSOUNDNESS, PIPING OR SEGREGATION.

SKETCH SHOWING THE UPPER PORTION OF THE INGOT, FORGED AND DRAWN OUT INTO A BAR 4¾ INCHES IN DIAMETER AND ABOUT 8 FEET IN LENGTH.

It must be borne in mind that this billet is one of several made from the same ingot. In other words, this particular billet represents only the *upper* portion of the ingot.

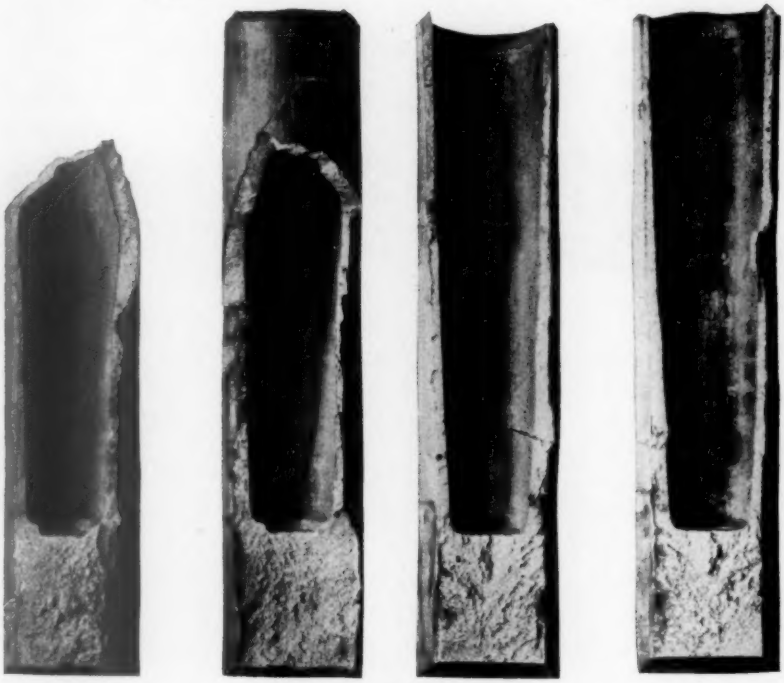
The material below this billet (that is, representing the ordinary or remaining portion of the ingot) is drawn out into the same kind of billets or bars of the same composition as the other billets, and in these, of course, the whole of the material is used.

The length marked *A* is the portion of the material from the top part of the ingot head which in the writer's system is cast in sand; that is, above the ingot itself. This portion, about 13 inches in length and representing 7.1 per cent. of the discard, was cut off. Below this the projectile forging known as "Blank No. 1" was prepared, as shown by the dotted lines in Fig. 7. Below

this, " Blank No. 2 " was taken after 10.4 per cent discard had been allowed. In other words, " Blank No. 1 " was made from the material now not used (that is, after 7.1 per cent. of the whole ingot was discarded), and " Blank No. 2 " after discarding 10.4 per cent.; this is also not now used. The further and following blanks, Nos. 3, 4, and upwards, are not shown, because this is un-

PLATE VIII.

FIG. 1. FIG. 2.



Photograph No. 2279

necessary, as such blanks then formed part of the current work. As will be seen, even " Blank No. 2 " could also have been safely used.

It is remarkable to find that the fracture from " Blank No. 1 " (that is, at the discard of only 7.1 per cent.) was perfectly sound, free from piping, and showed no signs of segregation. In the interior of the blank, after forging, there were some slight skin cracks proceeding from the hollow portion of the ingot top. The

projectile from " Blank No. 2 " was perfectly sound in every way, whether as regards surface fracture, freedom from segregation, piping, or any other defects; the interior was also perfectly sound. In other words, from this " Blank No. 2 " (that is, with only 10.4 per cent. discard) a perfectly sound projectile was obtained.

The two projectiles from " Blanks Nos. 1 and 2," after being split open, are shown in Plate VIII (photograph No. 2279). It will be seen that the fractures are sound and that in each case, even including the blank from the portion of the ingot with only 7.1 per cent. discard, the material would have etched quite sound and free from segregation.

As a result of this important research it is thus proved that it is now quite possible to obtain sound ingots which will give perfectly sound billets, blooms, rails, projectiles, etc., and yet with but small discard or loss of material. Therefore, there is effected not only an actual saving in cost of manufacture, but this is also accompanied by the highest quality of product, of a character not obtainable by the processes now used.

American users of rails, therefore, can now obtain material perfectly sound and safe, at the same time, on account of its greater soundness, possessing greater durability than at present, and this can be all accomplished with little or no increase in cost of material.

In conclusion, it will be seen that the case has been proved for the exercise of scientific methods and more care in the manufacture of ingots required for rolling into rails and other shapes, and upon many of which the safety of human life so largely depends. It has also been shown that perfectly sound steel is readily obtainable by methods which can be and are easily applied in practice. As a proof of this, the writer has now produced close upon 40,000 tons of ingots by the plan referred to in this paper. *Every one of these ingots* has been absolutely sound and free from blowholes, piping and segregation. If it is necessary, as most assuredly it is, to obtain sound steel, then it is clear that methods exist which enable this desirable result to be accomplished.

THE PHYSICS OF THE PHOTOGRAPHIC PROCESS.*

BY

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INTRODUCTION.

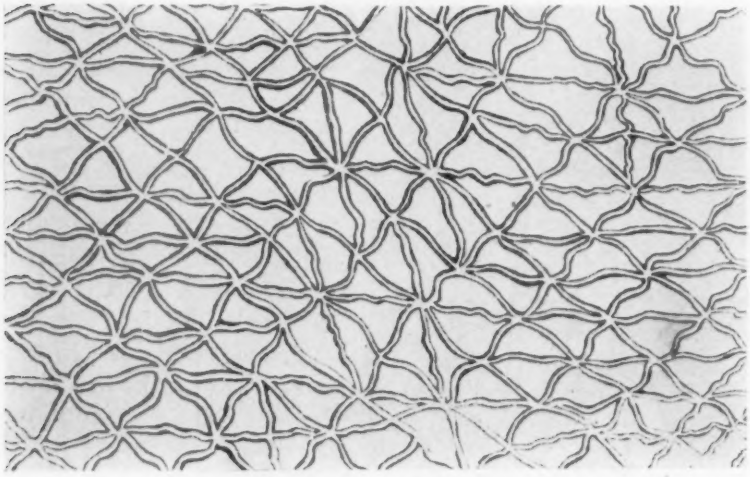
It is curious that, while many books and articles have been written about the chemistry of photography, very little has been written about the physical aspects of the subject, and such discussion as has been published on the physics of photography is chiefly contained in books or periodicals dealing with photographic chemistry, although the importance of the physical aspect of photographic processes completely overshadows the chemical aspect, and our views as to the nature of the reactions undergone on exposure to light and of the relation of the image produced to the exciting cause must be based rather on physical reasoning than on reasoning derived from the chemical standpoint. That this is likely to be the case will be obvious when we consider that photographic sensitive surfaces do not consist of continuous coherent films of homogeneous material, but have a definitely granular structure, the sensitive material itself consisting of grains imbedded in an insensitive matrix, so that in considering the properties of a sensitive material we are considering really the properties of a collection of sensitive grains which may appreciably differ from each other in their individual properties. The properties of such a collection will be the statistical average of the individuals composing it, and in order to understand the properties of a sensitive material we must therefore consider the properties of the individual grains and the relation of their properties to those of the aggregrate material of which they are units. In order to study the properties of the photographic grains, we must first consider their relation to the film in which they occur.

In the typical modern photographic materials this material is a sheet of gelatin, which when dry has a glassy structure and when

* Presented at the meeting of the Photographic Section held Thursday, October 29, 1914.

wet is a jelly. Quincke has suggested that gelatins have a structure similar to that of a sponge, consisting of two phases, the one a phase rich in gelatin and forming the walls of the sponge, and the other a liquid phase very weak in gelatin and filling the cells and passages which are formed by the stiff, strong phase. An attempt to represent this is shown in Fig. 1, while in Fig. 2 is shown the resultant structure which we must assign to a photographic emulsion, with the cells of the jelly filled by granular crystals of silver salt. Thus we see from Fig. 2 and from its enlarged view, Fig. 3, that we may consider an emulsion to consist of crystalline

FIG. 1.



SUGGESTED SPONGE STRUCTURE OF GELATIN.

granules of silver bromide inhabiting cells of a jelly which, on setting, surrounds each grain of the silver salt with a wall of gelatin. Of the structure of the grain itself very little is known. In high-speed emulsions it is probable that the grains consist of crystals, while in low-speed emulsions the grains themselves may be partly composed of gelatin separating still finer crystals of silver bromide.

Through the channels in the gelatin, ions and molecules can travel with ease at a velocity comparable with their diffusion rate in water, while penetration through the cell walls is a much slower and more difficult process. Diffusion into gelatin, and especially

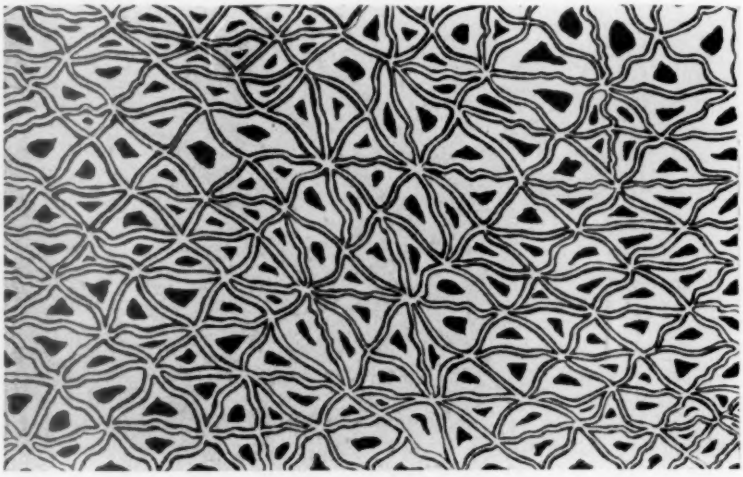
the diffusion of the developing solution into the emulsion film, may, therefore, be divided into two processes:

(*a*) Macro-diffusion, or the penetration of the solution through the channels of the gelatin; and

(*b*) Micro-diffusion, or the penetration through the walls, which is usually necessary to some extent before the developer can reach the silver halide grains.

When a delivery of goods is made in the city, the transportation to the house is very rapid, but relatively more time is required in getting the goods into the house, and a similar rule holds when a molecule visits the jelly: it travels rapidly through the channels, but slowly through the wall.

FIG. 2.



SILVER BROMIDE GRAINS IN GELATIN.

The Latent Image.—Now, when the developer reaches the grain, reaction takes place, and since reaction occurs only in solution, we must imagine this reaction to be with dissolved, and consequently with ionized, silver bromide, since silver bromide in solution splits up into silver ions and bromine ions. We must consider, therefore, that the silver bromide goes into solution to the extent represented by its solubility product, giving silver ions, and we have

$$AgBr = \overset{+}{Ag} + \overset{-}{Br}$$

and then, in the presence of a reducing agent, reaction occurs thus:

$$\overset{+}{Ag} + \overset{--}{R} = Ag + \overset{-}{R}$$

the silver ions losing their charge and producing silver molecules in solution.

This will then produce equilibrium unless the silver can precipitate, in which case more silver bromide will dissolve, which will precipitate as metallic silver in turn, and the reaction will proceed until the whole grain is dissolved and converted into metallic silver.

FIG. 3.

ENLARGED VIEW OF FIG. 2.

Suppose, however, that the silver cannot precipitate; then, since the solubility of the silver bromide is very small, the liquid around the grain will very soon be saturated and reaction will stop unless precipitation occurs. Now, precipitation in a saturated solution depends chiefly on the presence of a nucleus; for instance, a hot saturated solution of thiosulphate of soda can be kept for a long while without precipitating unless a nucleus of some kind is introduced. If anything which can form a nucleus

be introduced, however, the whole of the solution will go solid with the precipitation of the thiosulphate.

In the same way, if a nucleus of any kind be present in a sensitive grain, then on development silver will be deposited on the nucleus, more silver bromide will be dissolved, reduced, and deposited in turn, until the whole silver bromide grain has been transformed into metallic silver. When a grain once starts to develop, it will always completely develop, provided that it is supplied with sufficient developer and given sufficient time. Moreover, there is very little transference of silver bromide in solution from one grain to another; that is, the silver which forms a grain in the finished image is derived from the grain of silver bromide in that place and not from any other grains near by.

This has always been assumed, but the best proof of it was given by Kinoshita,[1] who showed that when alpha particles fell upon a photographic emulsion each particle made the grain which it struck developable, so that one grain of silver bromide was obtained for each alpha particle falling upon the plate.

In addition to light, other materials can produce a nucleus in the grain. For instance, treatment with auric chloride solution will produce a nucleus of metallic gold, and on adding developer to an emulsion treated with auric chloride all the grains will develop together, showing that a nucleus has been produced in every grain.

The action of light on the photographic emulsion has always been stated to produce a latent image, which by development was transformed into an image of silver, and the search for the philosopher's stone of photography has been that for the nature of this latent image, which from the earliest days has been the subject of continual speculation. The chemists at first thought that, since the long-continued action of light on silver bromide liberated bromine, the latent image must be a halide of silver, containing less silver than silver bromide, and ascribed to this the constitution Ag_2Br, which was termed silver sub-bromide.

Abegg considered the latent image to consist of a nucleus of metallic silver forming a solid solution in the silver bromide. Some other chemical theories of the latent image have also been suggested. An objection, however, that applies to all these theories is that the energy available during exposure is not suffi-

[1] Proceedings of the Royal Society, A 83 J. 432, 1910.

cient to produce an appreciable amount either of metallic silver or of silver sub-bromide from silver bromide. This was first pointed out by Hurter, who, from a consideration of the amount of energy which was liberated in the burning of a candle, came to the conclusion that the available energy was not 1 per cent. of that necessary to reduce to silver sub-bromide the silver grains which eventually proved to be developable. From this standpoint of available energy, the nature of the latent image can be attacked with results which, while not definitely making certain what its constitution must be, limit us in our conclusions so greatly that we find it necessary to abandon all ideas of a latent image consisting of grains materially different from silver bromide. The only means by which we can recognize the difference of exposed from unexposed silver bromide is by treating it with a developer, whereupon the exposed silver bromide is reduced, while the unexposed silver bromide is not. The difference between the two can be lessened and finally destroyed by the action of oxidizing substances, such as chromic acid. These are almost the only chemical facts which we have to guide us in our decision as to the nature of the latent image; that is, as to what happens to silver bromide when it is exposed to extremely small quantities of light energy. If the exposure is to large quantities of light energy, there is no doubt as to what happens. Bromine is given off, and the residue must consist either of silver sub-bromide or of a mixture of silver bromide and silver. The following statement, for which I am indebted to Dr. P. G. Nutting, as to the energy involved in the exposure of a high-speed photographic emulsion, would seem to suggest that, from a physical point of view, at any rate, and, therefore, from the chemical, it is quite certain what happens when the latent image is produced by a minimum exposure to light, and that the change is really the unit change that can be suffered by any substance when acted on by energy.

Consider the exposure to light which is sufficient after full development to produce a deposit of unit density; that is, one which will transmit one-tenth of the incident light.

A deposit which has this density contains ten milligrammes of metallic silver per square decimetre, or one-tenth milligramme per square centimetre, which represents roughly 10^{19} molecules of silver, or 10^{7} grains 3μ in diameter. Now, the energy of

the amount of violet light required to give an exposure necessary to make an emulsion film developable to this density, is of the order of 10^{-7} ergs per square centimetre. Therefore, each grain (which contains, on the average, 10^{12} molecules) receives 10^{-14} ergs to make it developable. Now, we know that, in order to detach one electron from a molecule, 5×10^{-12} ergs are required in the separate molecules of gas. This is a maximum amount, and it is possible that in the exposure of a photographic plate 10^{-14} ergs are sufficient to detach one electron. Clearly, then, the energy incident on a grain during exposure may be sufficient to affect only one molecule in that grain, and the latent image may be composed of grains in each of which, on the average, only one molecule has lost an electron by the action of light.

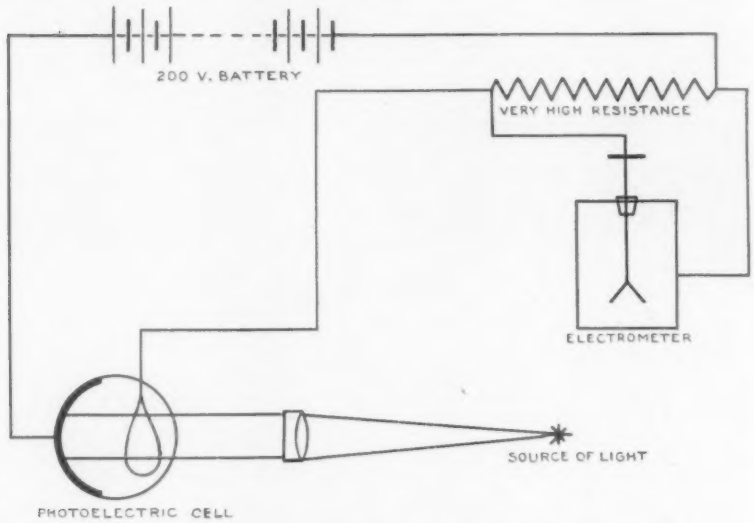
Now, if the action of light on the emulsion is to liberate an electron from the grain, its action is entirely analogous to that which light has on so many materials, the action which is termed the photo-electric effect, and Joly's suggestion, put forward a number of years ago,[2] that the exposure of a photographic emulsion is photo-electric in its nature, seems to be coming within reach of proof. If a beam of light falls on to a metallic surface which is attached to a negative pole of a battery, then, if the frequency of the light waves is high enough, electrons will be liberated from the metallic surface, and under the impressed voltage will be shot off with considerable velocity. A customary form of apparatus is shown in Fig. 4, the light here being shown as falling on an evacuated cell containing a surface of potassium metal, the number of electrons liberated being measured by the accumulated charge on the electroscope.

One of the most typical things about the photo-electric effect is that in order to produce any photo-electric effect the light must have a frequency above a certain critical value, this critical value depending upon the surface employed. The same is true of photographic emulsions. Fig. 5 shows the sensitiveness curve of silver chloride and silver bromide, and from this figure it can be seen that there is a critical value of the wave length, about $400\mu\mu$ for silver chloride and $480\mu\mu$ for silver bromide, above which the sensitiveness is extremely small and below which the sensitiveness for uniform energy is uniform. Photo-electric cells, by special

[2] *Nature*, 72, p. 308, 1905.

treatment of the surface, can be made to change their distribution of spectral sensitiveness, and in the same way photographic emulsions, by treatment with suitable dyes, can be made sensitive to regions of the spectrum other than those to which they are normally sensitive, the necessary conditions for the sensitizing dye being that it shall absorb in the region for which it is to sensitize, and that it shall dye the silver bromide itself, and not merely the gelatin. These conditions are by no means sufficient, as only

FIG. 4.



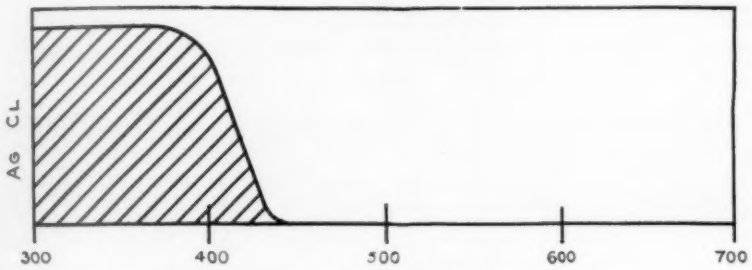
APPARATUS FOR DEMONSTRATING THE PHOTO-ELECTRIC EFFECT.

two main groups of dyestuffs sensitize to any great extent, these being the fluoresceins and a group of complex quinoline derivatives.

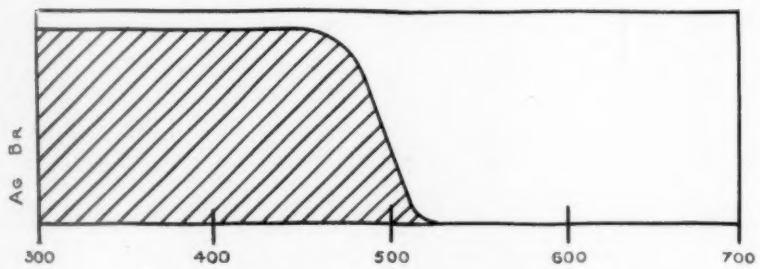
Reversal.—If for a photographic emulsion we plot a curve of the density against exposure, using for convenience a logarithmic scale of exposure, then at first the density increases rapidly with exposure, after a time increases less rapidly, and finally ceases to increase at all, and then, after a period begins to decrease somewhat, and finally, with very great exposures, again increases slightly (Fig. 6). This decrease in density with prolonged exposure is known as reversal, and any theory of photographic action must attempt to explain the region of reversal.

H. S. Allen, in his interesting monograph on photo-electricity,[3] suggests that the electrons expelled from the silver bromide may become attached to molecules of the surrounding gelatin, and if these molecules are now affected by external stimulus, such as radiation of longer wave-length, the electrons will be enabled to enter again into combination with the atoms from which they were liberated, this recombination being effected by the electrostatic forces between the oppositely charged particles. If

FIG. 5.



SENSITIVENESS OF SILVER CHLORIDE TO THE SPECTRUM.



SENSITIVENESS OF SILVER BROMIDE TO THE SPECTRUM.

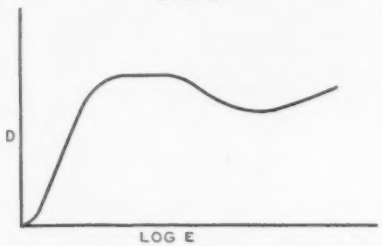
recombination is not assisted in this way, the electrostatic field will increase under the continued action of light, and self-neutralization will take place, as was suggested by Joly.

Now, while this explanation of reversal may be a possible one, I am a little skeptical about it, and it seems to me more likely that under the continual influence of light the silver bromide is broken up into metallic silver and bromine, as it is well known to do, the bromine given off from a much-overexposed plate being

[3] Longmans, Green & Co., 1913.

easily smelt. Now, bromine actually attacks exposed silver bromide, preventing it from being developed, so that it would seem likely that grains which have been completely decomposed by light, liberating the bromine, would be less easily developable than those which had simply suffered the photo-electric change to the latent image. The gain in density which is observed with still more extended exposure may be ascribed to the actual production of metallic silver by the long-continued action of light, and, indeed, such reduced silver can be shown to exist by fixing the exposed but undeveloped plate. We may, therefore, consider that there are probably three stages in the action of light on the photographic film: first, the photo-electric effect producing the latent image; second, dissociation of the

FIG. 6.



DENSITY-EXPOSURE CURVE SHOWING REVERSAL.

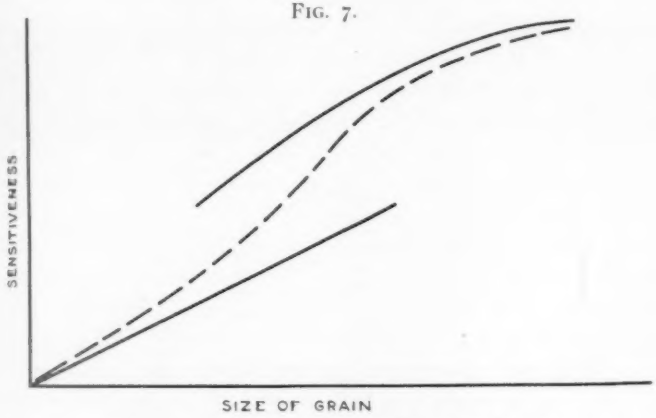
silver bromide involving liberation of bromine and destruction of some of the latent image produced; and, finally, visible blackening by the liberation of metallic silver.

The Effect of the Variation of Grain Size on Various Properties of Photographic Materials.—Very little has been published on the effect of the difference in the size of grain of different emulsions upon their properties. Four different aspects of the question have to be considered. The first is the effect of grain size on sensitiveness; second, the effect on gradation; third, the effect on the color of the silver deposit; and fourth, the effect on the resolving power.

Now, from the earliest days it has been known that the more the size of the grain increased the more sensitive the emulsion, and that the grain of high-speed emulsions was coarser than that of low-speed emulsions; but it has not been so generally recognized that the difference between high- and low-speed emul-

sions is not simply one of size of grains, but that there is a qualitative difference between them which must be due to the nature of the grain. Thus it might be assumed that if we took an emulsion, starting with a very fine grain, and cooked it, we could increase the sensitiveness uniformly, as is shown in the dashed curve of Fig. 7. Actually, however, if we start with a very fine-grained emulsion and cook it, the size of grain and the sensitiveness only increase to a certain limited extent, as is shown in the lower solid curve, and in order to get a high-speed emulsion having larger grains and much greater sensitiveness, we must start in an entirely different manner, precipitating the silver of medium grain, which can then be increased in size with a con-

FIG. 7.



GROWTH OF SENSITIVENESS WITH SIZE OF GRAIN.

comitant increase of sensitiveness, as is shown in the upper solid curve, and no direct transformation of an emulsion which has been ripened from a very fine grain into a high-speed emulsion seems to be possible. The difference may be that in the low-speed type the silver grain consists of a network of crystals containing gelatin, while in the high-speed emulsions the gelatin is distinctly separated from the crystals, so that in a low-speed emulsion each of the crystals forming part of the grain must be made developable by the action of light, while the large grain of the high-speed emulsions requires action only at one point to make it entirely developable, so that the energy required to form a latent image in a high-speed emulsion is only that necessary for the liberation

of one electron per grain, while in the low-speed emulsion several electrons for each grain may be necessary.

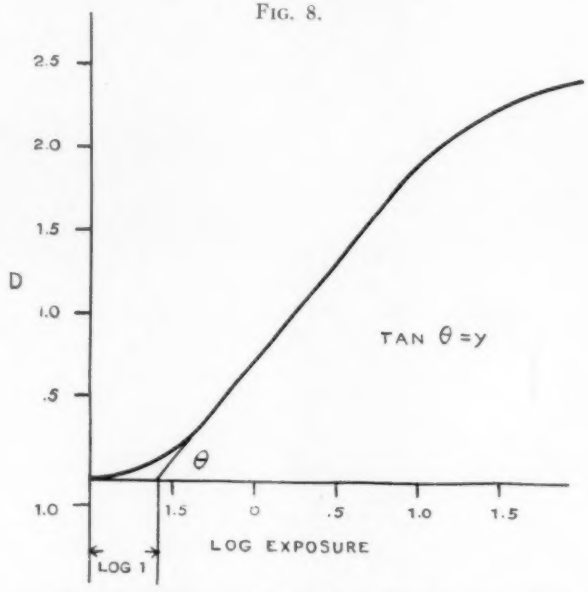
Considering, first of all, the effect of size of grain on the sensitiveness of high-speed emulsions, let us assume that the amount of energy required to make any grain developable is the same, whatever the size of the grain. Now, it has been shown both experimentally and theoretically, that the density is equal to a constant times the mass of silver per square centimetre, the constant applying only to different densities in the same emulsion, though it varies very little throughout all high-speed emulsions, the value being approximately 1/10 mg. per square centimetre for a density of unity.

Now, since the mass of silver is equal to the number of grains multiplied by the cube of the diameter, and if all the grains, whatever the diameter, required the same amount of energy to make them developable, then for two given exposures on different sizes of grain the density produced for a given exposure will vary as the cube of the diameter of the grain.

In high-speed emulsions, grains vary in diameter from about 1 to 3μ, so that this mere variation of size, without any difference in the sensitiveness of the single grains, would give a range of sensitiveness from 1 to 27 in high-speed emulsions, supposing that these emulsions can be made homogeneous. Inasmuch as the emulsions are not homogeneous, but each emulsion will contain grains of all sizes, the sensitiveness will depend upon the distribution of the different sizes of grains, and so also will the shape of the plate curve, this plate curve being the relation between the density and the logarithmic exposure. This curve was first plotted by Hurter and Driffield, and afterwards by Eder, both of them terming it the characteristic curve of a plate. It has the shape shown in Fig. 8. It will be seen that throughout a considerable portion of the curve the density is proportional to the logarithmic exposure, and through this portion the range of light intensities in the original is correctly reproduced by the absorption of the negative. At the beginning of the curve, in what is termed the period of under-exposure, the density rises less rapidly than the logarithmic exposure, and at the top of the curve, in what is termed the period of over-exposure, the density fails to rise in the correct proportion, and finally becomes constant, this constancy continuing for a long period, after which reversal sets in,

as has previously been explained. Now, the shape of this curve depends to a considerable extent on the distribution of the different sizes of grain in the emulsion. With a homogeneous emulsion we should have a simple curve with short over- and under-exposure portion, as shown in Fig. 9, and by adjusting the sizes of grain so that there is a sufficient number of grains distributed around the mean we can diminish the size of the under-exposure portion and obtain a longer straight line (Fig. 10). We can, therefore, form a mental picture of the relation between the dis-

FIG. 8.



CURVE SHOWING RELATION BETWEEN DENSITY AND EXPOSURE.

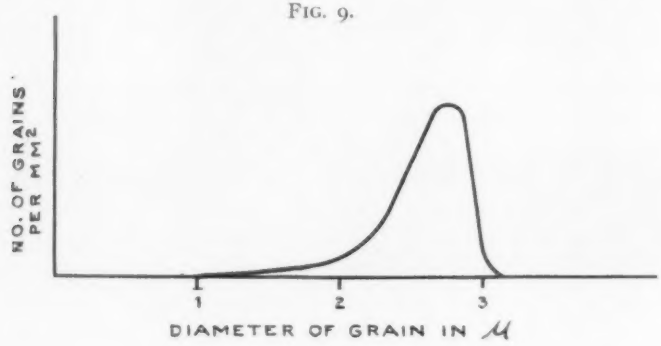
tributions of the grain and the sensitiveness curve. Up to the present there has been very little experimental work done on this subject, the work having only just been commenced, but I venture, in Figs. 9, 10, and 11, to show what I consider may be the relation between some distributions of grain and the resultant sensitiveness curves.

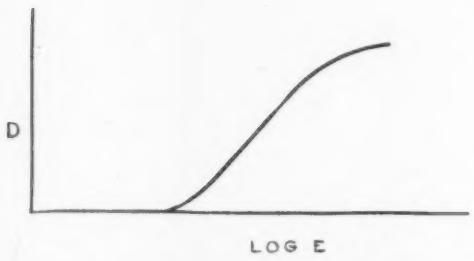
Fig. 9 shows the case of an approximately homogeneous emulsion with a mean grain size of about 2.6μ, the upper curve showing the number of grains of each size in a given area plotted against their diameters. Such an emulsion gives a curve with a short

straight line, little under-exposed portion, and a low inertia, the curve being well to the left.

In Fig. 10 a much less homogeneous emulsion is shown, the larger grains being of the same size as those in Fig. 9, but the average grains being only about 2.2μ, and the emulsion containing a much larger proportion of small grains. The result of this is that, while the lowest densities are obtained at the same point as the emulsion shown in Fig. 9, the inertia is somewhat greater

FIG. 9.





D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (1).

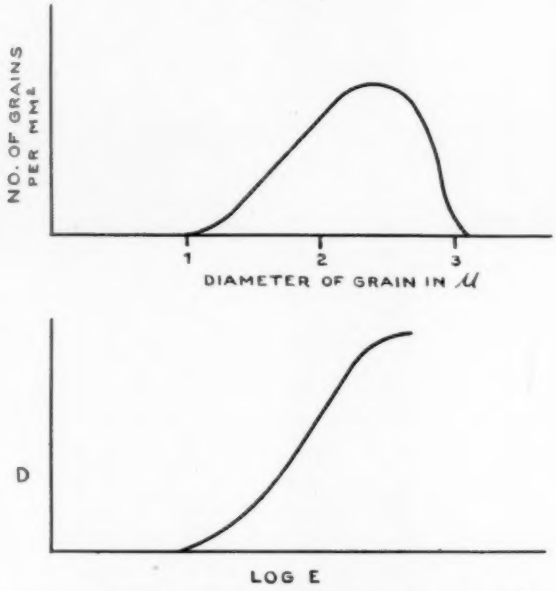
and the straight line is much longer, the large number of small grains enabling the density to go on growing with the exposure after a homogeneous emulsion has all its grains exposed.

In Fig. 11 a distribution of grains is seen resulting from the mixture of two different emulsions, one a low-speed, fine-grained emulsion, and the other a high-speed, coarser-grained emulsion; the resulting curve again shows the commencement of action at the same point, but now we have a very long under-exposure

portion, due to the large grains, and then a straight line, due to the finer-grained portion of the emulsion.

Turning to the question of the effect of grain size on low-speed emulsions, the first effect is on covering power; that is, on the amount of density that can be obtained from a given weight of silver. Clearly, the smaller the grain, the greater the surface for a given mass, and consequently the greater the covering power, so that the finer-grained emulsions will require less silver than

FIG. 10.

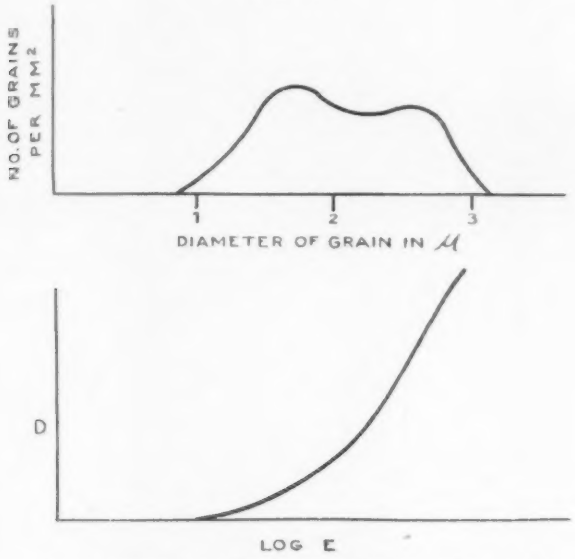


D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (2).

coarse-grained. As in the case of high-speed emulsions, the sensitiveness of low-speed emulsions is, to some extent, dependent on the sizes of the grain, but it is improbable that in the case of the low-speed emulsions we can trace so simple a relation between the sensitiveness and size of grain as we should be able to with the high-speed type. In the high-speed emulsions, as has previously been explained, there is some justification for assuming that the amount of energy required by an individual grain to make it developable can be considered a constant quantity, it being that necessary to liberate an electron; but in the low-speed

emulsions the grains are very complex, and, as the complexity will vary from grain to grain, we have no right to assume that the same amount of energy will make different grains in low-speed emulsions developable. The complex grains of low-speed emulsions may, for instance, require a unit quantity of energy for each separate unit of the complex, in which case the amount required will vary from grain to grain throughout the emulsion, and the sensitiveness of the emulsion will depend not only on the size of the complex grains but on their complexity.

FIG. 11.



D-LOG E CURVE AND GRAIN DISTRIBUTION CURVE (3).

Another effect of the size of the grains in low-speed emulsions is the effect on the color of a deposit. If the silver grains, after development, approximate in diameter to half the length of a light wave, then they will have a selective absorption for light of wave-lengths approximately twice their diameter, and the silver deposit will consequently appear colored. Such colored deposits can be obtained with slow developing papers or lantern slides by using a developer in which the deposition of the silver is restrained by the addition of silver solvents, so as to produce a very slow deposition from a solution rich in silver. The result

is to produce colors which, though not brilliant, are yet distinctly pleasing.

Resolving Power.—In many applications of photography it is necessary to get as sharp images as possible, and the inhomogeneity of the sensitive film has always been a source of distress in some classes of work, because of the way in which the silver image is broken up by the grains composing it. The relation, however, between the fineness of detail that an emulsion can give and the size of the grains is not quite as simple as it appears at first sight.

This subject was first studied by Wadsworth, and, in view of his work, the matter is discussed by Baly.[4] Baly states that it can be assumed that on a negative two lines can be separated if between the grains at the maxima of the lines there are one silver particle and two spaces, so that in photographic resolution it is necessary that the linear distance between the centres of the lines should be four times the diameter of a grain. Now, inasmuch as the diameters of grains are from 1 to 3μ (Baly wrongly states them to be from 5 to 25μ), this rule should give us a resolving power of from 4 to 12μ, an amount which is much above that found in practice.

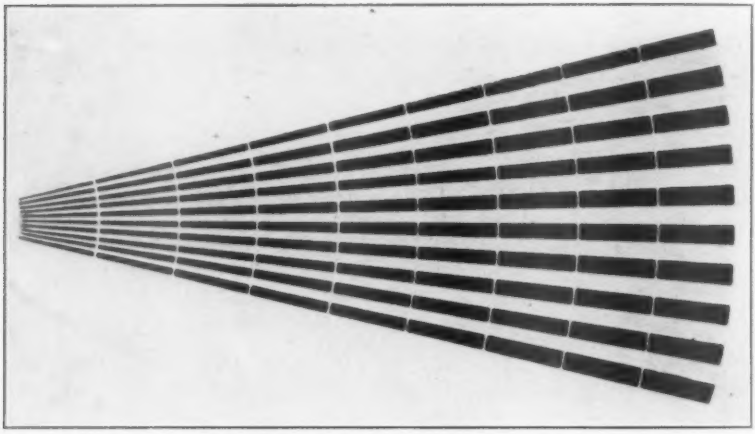
The writer started work on this subject in 1907 in the following manner: A tube about twenty feet long was taken, and at the end of this the object was placed; at the other end was fastened a small camera made of a heavy brass tube, to which was bolted a brass face plate, against which the face plate of a plate holder could be placed. This camera carried the lens in a very solid mounting, this being a spectroscope objective of high aperture which on test worked up to its theoretical resolving power. The first object photographed was a small slit covered with a black wedge so as to get a gradation of intensity down the slit, but it was soon clear that it would be better to have a numerical expression of resolving power, and at first this was done by photographing line gratings with different sizes of lines until one was found which would only just resolve. Finally, however, a converging grating was made as shown in Fig. 12, and by photographing this the point could be observed in the photograph at which resolution first occurred, and, as the spacing of the grat-

[4] "Spectroscopy," Longmans, Green & Co., p. 339.

ing was known, a numerical expression for resolving power could be found. While this method is still convenient for the practical testing of emulsions, it introduces a number of systematic errors which prevent it being suitable for a final investigation as to the nature of resolving power.

Goldberg [5] took up the subject by printing contact images of small apertures on the plate. He showed that there were two factors in the resolving power: one an optical factor, which he termed the turbidity factor, depending on the scattering of the light in the emulsion, and the other the photographic factor,

FIG. 12.



RESOLVING POWER TEST OBJECT.

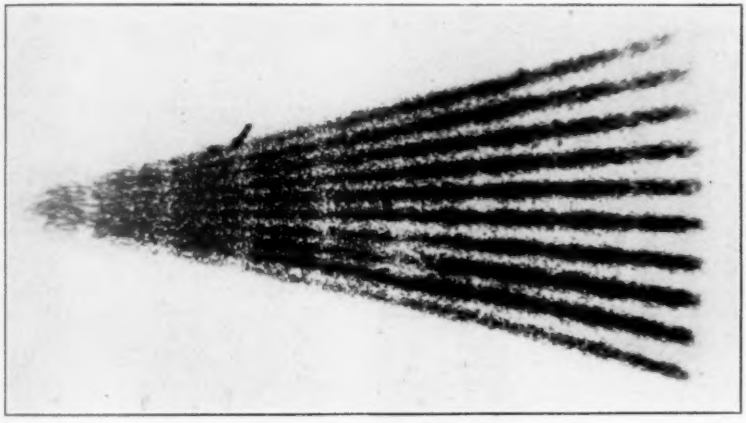
which gives the translation of the distribution of light in the emulsion into the distribution of silver after development.

The subject has again been taken up in our laboratory by Dr. Nutting,[6] who, instead of using apertures, has printed images of the edge of a steel blade on the plate by parallel light, and this work is still going forward on the experimental side. Dr. Nutting points out that the optical factor of turbidity can be split into two separate factors: the one the turbidity of the emulsion in the strictest sense, that is to say, its scattering power for light, and the other the opacity of the emulsion or its stopping power for

[5] *Photographic Journal*, November, 1912.
[6] *Photographic Journal*, June, 1914.

scattered light. An emulsion having high turbidity and low opacity will have a very low resolving power; on the other hand, even if the emulsion has high turbidity, if its opacity is also high, its resolving power may be good. A typical example of this is the wet collodion plate, in which the turbidity is considerable, but where the opacity of silver iodide for blue-violet light is so great that the resolving power is very high. In a Lippman emulsion the resolving power is high if the emulsion is very clear, because the turbidity is very small, but the opacity is also small, and the slightest increase in turbidity may make the resolving power very low. An interesting experiment which I have made was as

FIG. 13.

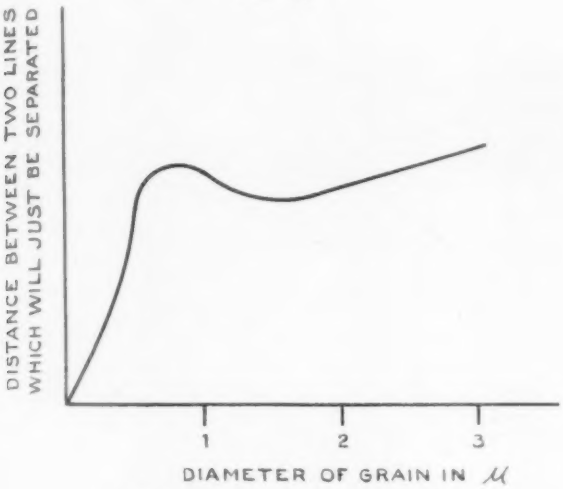


REPRODUCTION OF TEST OBJECT ON A PLATE.

follows: I made a Lippman emulsion, coated it, and found the resolving power, which was very high. Some of the emulsion was slightly warmed so that it increased in speed somewhat and showed slight turbidity, and, although the increase in speed was quite small, the resolving power was now very poor. By further heating the emulsion so that it became visibly opaque, with a considerable increase of speed, although the turbidity was now high, the opacity had risen sufficiently to give the emulsion a considerably better resolving power than after the first heating had taken place. The relation of the resolving power of emulsions to the size of the grain may, therefore, be roughly expressed somewhat as shown in Fig. 14.

The distance between the two lines which will just be separated with a given emulsion will be extremely small for extremely small sizes of grain, because such sizes of grain far below the wavelength of light will scatter very little light; that is, the turbidity will be negligible. As the size of grain rises, however, the turbidity increases very rapidly, and with it the distance necessary to separate two lines, until with a grain diameter a little less than 1μ the turbidity is high and the opacity still low, so that the necessary separation of the lines is a maximum, and then, as the grain still grows, the opacity grows faster than the turbidity and

FIG. 14.



RESOLVING POWER AND GRAIN SIZE.

the lines to be separated can be somewhat closer together. Then, again, with the increasing diameter of the grains the actual space factor comes in, the size of the grains themselves and the distance between them becoming comparable with the distance between the separated lines, and with increasing size of grain this distance must again increase steadily. It must be understood that Fig. 14, like the other figures occurring in this paper, is not intended to be drawn to scale or to be a quantitative representation in any way. It is simply an illustration of the general trend of the effects, being a purely general curve drawn free-hand in the absence of any quantitative data.

ON THE BOILING-POINT OF AQUEOUS SOLUTIONS OF NITRIC ACID AT DIFFERENT PRESSURES. PART I.*

BY

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AND

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INTRODUCTION.

THE composition of the vapor formed by the evaporation of a mixture of two liquids depends upon the proportion in which the components are contained in the mixture, and upon the individual vapor pressures of these components at the temperature at which evaporation occurs. The vapor pressure of each component of a liquid mixture is always less than the vapor pressure of the component in the pure state; but whether, in the case of infinitely miscible liquids not closely related, the total vapor pressure of the mixture is greater or less than that of either of the pure components depends upon the proportions in which they are present, upon the relative attraction between the like and unlike molecules, and upon the solubilities of the vapors in the unlike components of the liquid mixture. For a mixture containing two liquids, A and B, the dependence of the vapor pressure of the mixture upon the solubility of the vapors in the liquid may be illustrated by three well-known cases: when the vapor of A is but slightly soluble in liquid B and that of B but slightly soluble in liquid A, the vapor pressure of the mixture is greater than the square root of the product of the vapor pressures of the two components; when the vapor of A is soluble in liquid B and that of B soluble in liquid A, the vapor pressure of the mixture is less than the square root of the product of the vapor pressures of the two components; and, thirdly, when the vapor of A is but slightly soluble in liquid B and that of B soluble in liquid A, the vapor pressure of the mixture is equal to the square root of the product of the vapor pressures of the two components. In the second of these cases, the component which is in excess evaporates more rapidly than the other, and there is finally left behind a residual mixture which

* Communicated by Professor Creighton.

evaporates unchanged in composition; *i.e.*, a mixture of minimum vapor pressure.

The occurrence of mixtures of maximum boiling-point (minimum vapor pressure) is fairly rare. In the majority of cases where the formation of such mixtures has been observed, one of the components is an acid and the other a base or a liquid of basic character. Among the more common examples of mixtures of maximum boiling-point are aqueous solutions of most of the strong mineral acids.

The composition of the mixture of maximum boiling-point of nitric acid and water has been investigated at different pressures by Roscoe,[1] who has shown that aqueous solutions of nitric acid of widely different degrees of concentration attain on boiling, at atmospheric pressure, a mean composition of 68 per cent. real acid. When aqueous solutions of nitric acid are heated under diminished pressure, Roscoe has shown that, at 70 mm. of mercury, a residual liquid having a constant mean composition of 66.7 per cent. of nitric acid is obtained, while under a pressure of 150 mm. of mercury equilibrium occurs when the percentage of nitric acid in the residual mixture reaches 67.6. At 1260 mm. of mercury he has found that the mixture of maximum boiling-point contains 68.8 per cent. of acid. It will be seen, from the foregoing figures, that the acid content of the mixture of maximum boiling-point increases slightly with pressure.

When, for a constant pressure, the boiling-points of mixtures of two components which form a mixture of maximum boiling-point are plotted on the axis of ordinates against the percentage of one of the components of the mixture on the axis of abscissæ, the curve obtained rises gradually as the percentage of the component increases, reaches a maximum, and then rapidly declines. The composition of the mixture corresponding to the maximum of the curve is that of the mixture of maximum boiling-point. It is our intention to determine and study the boiling-point curves of aqueous solutions of nitric acid over a large range of pressure, and to ascertain, from the positions of the maxima of the curves, how the composition of the mixture of maximum boiling-point changes with pressure.

The present communication deals with the results of measurements made at atmospheric and diminished pressures.

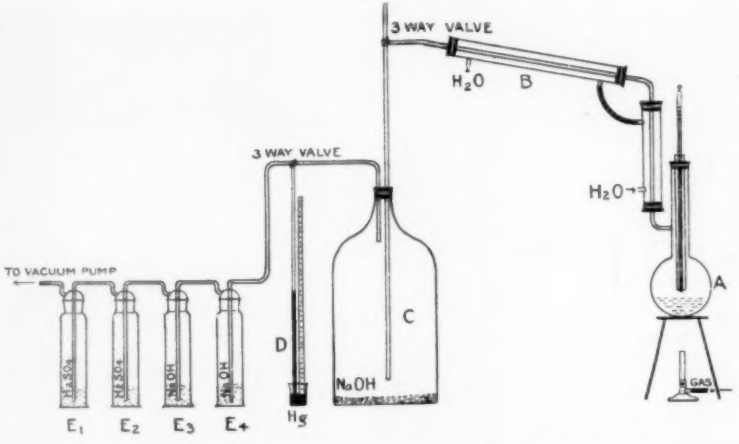
[1] Roscoe, H. E., *Journ. Chem. Soc.*, **13**, 146 (1861).

EXPERIMENTAL.

The boiling-points and vapor pressures of mixtures of nitric acid and water were determined by the dynamical method.

The flask in which the aqueous mixtures of acid were heated was similar to that described [2] by Young. To the wide, long neck of a flask having a capacity of 200 c.c. a side-tube is sealed. This side-tube is bent upwards at right angles about 10 cm. from the neck of the flask, and the vertical portion cooled by a water-jacket so that it acts as a reflux condenser. The end of the wide neck of the flask is provided with a well-fitting cork, through which passes a narrower, thin-walled glass tube which

FIG. 1.



has a hole blown in it a little below the cork. This narrower tube is also closed with a cork, through which passes a thermometer graduated in $^1/_{10}$°. This flask is shown in Fig. 1, at *A*.

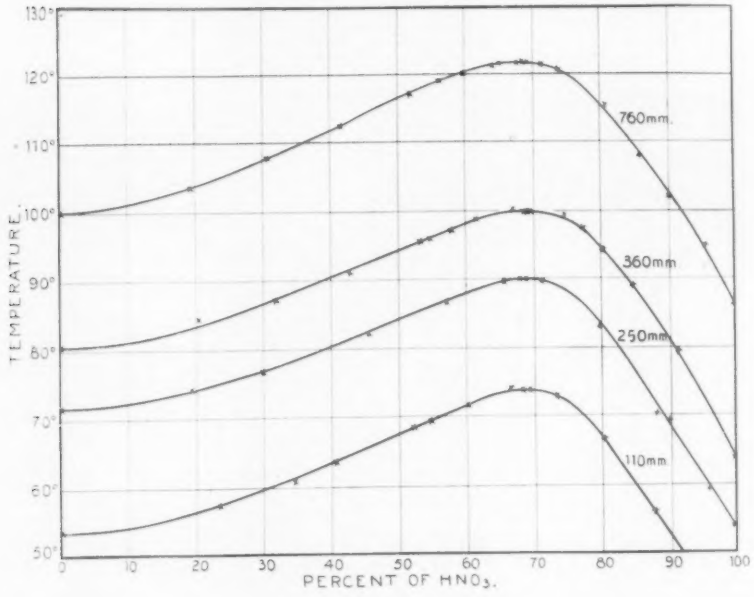
As it is important that the volume of the vapor should be relatively small to that of the liquid, the flask is filled to two-thirds its capacity. The thin-walled tube is pushed down until the bottom is about 3 mm. above the surface of the liquid. The end of the bulb of the thermometer is about level with the bottom of the thin-walled tube.

As Young points out, this apparatus possesses the following advantages: " (1) The liquid that returns from the reflux condenser

[2] Young, S., *Journ. Chem. Soc.*, **81**, 772 (1902).

cannot come near the thermometer, and the amount of liquid which condenses on the thermometer and on the thin walls of the thin-walled tube is exceedingly small; on the other hand, with the large quantity of liquid which is present and the small flame that is required there is no fear of the vapor being superheated. (2) It is possible to take readings of the temperature of the vapor and of the boiling liquid without altering the position of the thermometer, for when the burner is directly below the centre of the bulb

FIG. 2.

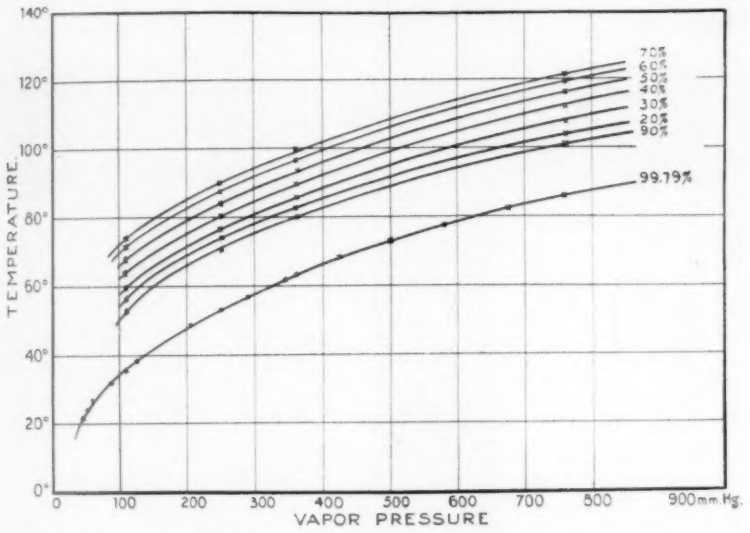


the liquid boils up into the thin-walled tube well above the thermometer bulb, but when the burner is moved a little to one side the surface of the liquid immediately below the thin-walled tube remains undisturbed and the liquid does not come in contact with the thermometer bulb." The values for the boiling-points given in the following tables refer to the temperature of the vapor immediately above the boiling liquid.

The apparatus described above was employed to determine the boiling-points at atmospheric pressure, and from the values ob-

tained the boiling-points at 760 mm. pressure were calculated.[3] In all boiling-point determinations the thermometer readings were corrected for the cooling of the mercury thread which extended above the top of the neck of the flask.[4] When boiling-point determinations were made at diminished pressure, the apparatus shown in Fig. 1 was employed. In this figure, A is the boiling flask previously described; B is an additional reflux condenser; C is a bottle with a capacity of 30 litres, the bottom of which is covered to a depth of several centimetres with a solid sodium hydroxide; D is a mercury manometer, and E_1, E_2, E_3, and E_4 are

FIG. 3.



wash bottles which remove the last traces of nitric acid and water from the gas before it passes to the Geryk pump used for evacuating the apparatus. Bumping was practically prevented by placing several sharp pieces of platinum at the bottom of the boiling flask. The aqueous solutions of nitric acid were heated to boiling, and, after the boiling-point became constant, the liquid remaining in the flask was quickly cooled and its nitric acid content determined by analysis.

Before studying the boiling-points of mixtures of water and

[3] Kahlbaum, G. W. A., *Ber.*, **19**, 3101 (1886).

[4] Rimbach, E., *Ber.*, **22**, 3072 (1889).

nitric acid, a number of measurements were made of the boiling-points of pure nitric acid at different pressures. Pure acid was obtained by distilling a mixture of equal volumes of concentrated sulphuric acid and c. p. nitric acid under reduced pressure, and then redistilling the distillate thus obtained with an equal volume of concentrated sulphuric acid. The second distillate, which was yellow in color, was gently heated to 45°, after which a current of pure, dry air was bubbled through the acid until it became cold. By this means practically all the dissolved nitrogen peroxide was removed and an acid having a pale lemon color was obtained. The density (*in vacuo*) of this acid was $d\,\frac{25^\circ}{4^\circ} = 1.5049$. Analysis showed that the acid contained 99.79 per cent. HNO_3. In Table I is shown the boiling-point of this acid at a number of different pressures. The change in vapor pressure of pure nitric acid with temperature is shown graphically in Fig. 3.

TABLE I.

99.79 PER CENT. HNO_3.

Pressure, mm. Hg	Boiling-point, degrees	Pressure, mm. Hg	Boiling-point, degrees
47	22.1	290	57.1
51	24.5	346	62.1
60	26.2	360	63.4
90	31.7	425	68.5
110	35.6	500	72.7
125	38.5	580	77.2
203	49.0	675	82.5
250	53.5		

The boiling-points of aqueous mixtures of nitric acid at 760 mm., 360 mm., 250 mm., and 110 mm. pressure, and their composition, are given in Table II. Isobaric curves showing the change in the boiling-point with variation in the composition of the mixture are shown in Fig. 2. It will be seen that the curves are fairly parallel and that their shape is characteristic of a mixture of maximum boiling-point. From the data contained in Tables I and II, curves showing the change in vapor pressure with change in temperature have been constructed for a number of different aqueous mixtures of nitric acid. These curves are shown in Fig. 3. The percentages in this figure refer to nitric acid.

TABLE II.

Pressure = 760 mm.		Pressure = 360 mm.		Pressure = 250 mm.		Pressure = 110 mm.	
Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees	Per cent. HNO_3	Boiling-point, degrees
19.37	103.56	20.30	84.7	19.51	74.5	23.61	57.5
30.43	108.08	32.05	87.2	30.02	76.6	34.54	60.7
41.38	112.59	42.75	91.1	45.42	82.1	40.44	63.6
51.63	116.85	53.14	95.4	56.91	86.4	51.74	68.3
56.01	118.88	54.67	95.8	65.34	89.4	54.42	69.4
59.77	120.06	57.72	97.2	67.91	89.9	60.21	71.6
63.89	121.27	61.26	98.7	68.72	89.9	66.78	74.3
65.17	121.66	67.25	100.0	71.24	89.6	68.32	73.9
67.74	121.67	68.46	99.8	79.50	83.1	68.53	73.6
68.18	121.79	68.91	99.9	87.93	70.4	69.42	73.8
69.24	121.80	69.61	99.9	90.04	69.5	73.12	73.1
71.10	121.60	74.39	99.6	95.76	59.1	80.61	66.8
73.56	120.75	76.92	97.4	99.79	53.5	87.62	56.5
80.50	115.45	80.21	94.0			94.31	45.0
85.51	108.12	84.41	89.1			99.79	35.6
90.06	102.03	91.31	79.5				
95.45	95.42	99.79	63.4				

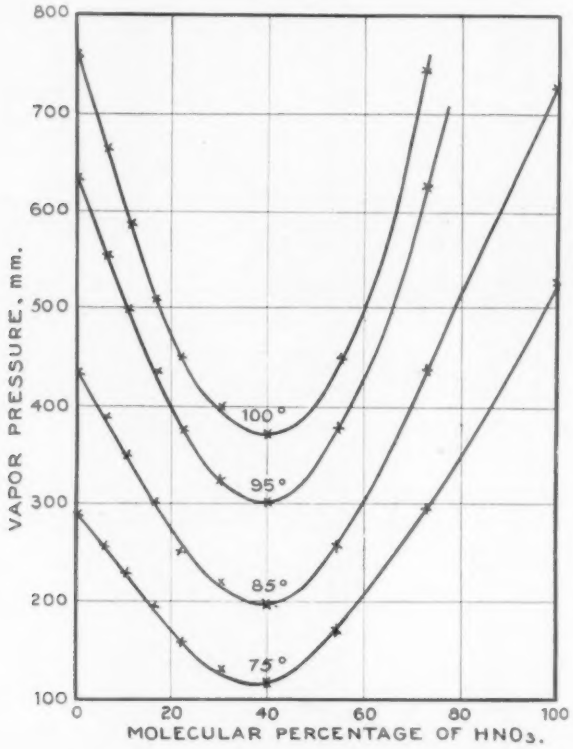
In Table III is given, for several temperatures, the change in the vapor pressures of aqueous solutions of nitric acid with the variation of the molecular percentage of nitric acid (number of moles of nitric acid per 100 moles of mixture) in the solutions. These isothermal changes are shown graphically in Fig. 4. The shapes of the curves in this figure are characteristic of mixtures of minimum vapor pressure.

TABLE III.

Per cent. HNO_3 by weight	Molecular percentage of HNO_3	Vapor pressure at			
		75°	85°	95°	100°
		mm. Hg	*mm. Hg*	*mm. Hg*	*mm. Hg*
0	0	289	434	634	760
20	6.7	260	390	554	663
30	11.0	230	350	497	585
40	16.8	195	300	435	510
50	22.0	155	250	375	450
60	30.2	135	225	330	405
70	40.1	115	195	300	370
80	53.5	170	250	375	450
90	72.6	295	440	625	745
100	100	524	725	...	...

As is to be expected with mixtures of maximum boiling-point, it has been found, on examining the curves given in Fig. 3, that the square root of the product of the vapor pressures of water and pure nitric acid, for any given temperature, is always greater than the vapor pressure of any mixture of nitric acid and water at that temperature. It is evident, from the position of the maxima

FIG. 4.



of these curves, that the composition of the mixtures of maximum boiling-point formed by nitric acid and water changes but slightly with pressure. In order to confirm this, a number of determinations of the boiling-point and composition of the mixture of maximum boiling-point of nitric acid and water were made at 760, 360, and 110 mm. pressure. The results obtained are recorded in Table IV. In all determinations, 500 c.c. of the aqueous solu-

tion of nitric acid were placed in the distilling flask, the mixture then distilled until the temperature became constant, and distillation continued until only 15 to 20 c.c. of the liquid remained in the flask. The nitric acid content of this residual mixture was then determined by analysis with standard barium hydroxide. The mean values for the composition of the mixtures of maximum boiling-point in the following table are in good agreement with those previously determined by Roscoe.[5]

TABLE IV.

Composition of mixture before distillation, HNO_3	Mixture of maximum boiling-point at:					
	Pressure = 760 mm.		Pressure = 360 mm.		Pressure = 110 mm.	
	Composition, HNO_3	Boiling-point, degrees	Composition, HNO_3	Boiling-point, degrees	Composition, HNO_3	Boiling-point, degrees
60	67.90	121.80	66.95	99.8	66.73	74.2
65	68.28	121.57	67.20	99.7	66.77	74.2
67	67.96	121.59	67.15	99.7	66.81	74.1
68	68.17	121.58	67.08	100.1	66.78	74.3
69	68.24	121.67	67.16	99.9	66.82	74.1
70	68.18	121.79	67.24	100.1	66.85	73.9
71	68.35	121.85	67.18	100.0	66.87	74.3
80	68.36	121.76	67.25	100.0	66.79	74.4
Mean:	66.18	121.70	67.15	99.9	66.80	74.2

In conclusion, we wish to mention that experiments are now in progress, in this laboratory, on the determination of the vapor pressure of aqueous solutions of nitric acid at high pressures.

Chemical Laboratory,
Swarthmore College,
Swarthmore, Pa.

Electrolytic Iron. ANON. (*Sci. Amer.*, cxi, No. 2, 23.)—Considerable time has been required to make electrolytic iron available for industrial use, because it contained much hydrogen, due to the action of the current in the process. This makes it brittle and unsuitable for practical work, so inventors have been trying to get rid of the hydrogen and make metal of the usual quality. At the coming Lyons Exhibition samples of the new iron are to be presented in the shape of seamless iron pipe, which possesses great tenacity and ductility.

[5] Roscoe, H. E., *loc. cit.*

Production of Petroleum in Canada in 1913. ANON. (*Oil, Paint and Drug Reporter*, Aug. 31, 1913.)—The Department of Mines reports that the total output of petroleum in 1913 was 228,080 barrels, or 7,982,798 gallons, on which a bounty of $119,741.97 was paid. The total value of the production, at the average price for the year, $1.782 per barrel, was $406,439. The total imports of petroleum oil, crude and refined, in 1913 were 222,779,293 gallons, valued at $13,230,429, in addition to 1,628,387 pounds of wax and candles, valued at $108,897. The oil imports included crude oil 162,062,201 gallons, refined and illuminating oils 19,393,827 gallons, gasoline 29,525,170 gallons, lubricating oils 6,789,451 gallons. There was an increased importation in 1913 of all classes of oil with the exception of gasoline, the increases being most pronounced in crude oil and refined illuminating oil. There was comparatively little change in the production of natural gas in Ontario, but a large increase in the production in New Brunswick and Alberta. The total production in 1913 was approximately 20,345,000,000 feet, valued at $3,338,314, of which 828,000,000 feet were from New Brunswick, 12,487,000,000 feet from Ontario, and 7,030,000,000 feet from Alberta.

Ceresin Wax. E. J. PARRY. (*Chem. and Drug.*, lxxxv, 376.)—Paraffin waxes of different kinds have recently been adulterated with large quantities of rosin. The samples were sticky, showed uncertain melting-points, and tasted of rosin. They gave the color reactions for rosin, and had high acid and iodine values. Four samples gave: Acid value, 48 to 60; saponification value, 51 to 72.5; and iodine value, 40 to 56.

"New" or "Double" Gas for Small Plants. C. B. TULLY. (*J. Gas Lighting*, cxxvii, 452.)—"Double" gas is a mixture of coal gas and water gas, having a calorific power from 380 to 400 B.T.U., made by the gasification of coal and the generation of water gas from the resulting coke in the same plant. The gas can be made in small gas-works (5,000,000 cubic feet per annum) and sold more profitably at 2s. 6d. (60 cents) per 1000 cubic feet than coal gas (550 B.T.U.) at 6s. 3d. ($1.50). It is suitable for heating, and can compete with suction producer gas for gas engines. The plant consists of two gas-producers connected at the lower part, each surmounted by a vertical retort chamber surrounded by chequer-brickwork. The producers are "blown" to incandescence for about one minute by an up-draught, and the hot gases burned with a secondary air supply in the chequer-brickwork around the retorts, coal gas passing from the retorts to the scrubber during this period. Steam is then passed downwards through the hot chequer-brickwork of one producer, then through the two producer chambers in series, and upwards through the second retort chamber. During the next gas-making period the direction of flow is reversed.

RECENT DEVELOPMENTS IN CAST-IRON MANUFACTURE.*

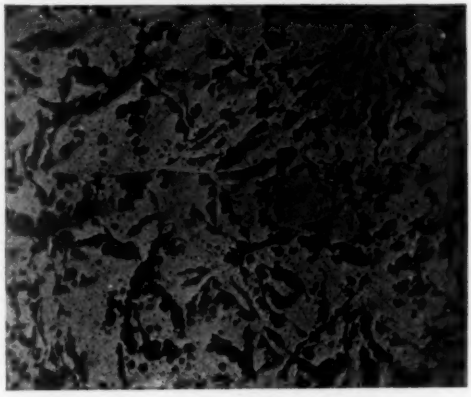
BY

J. E. JOHNSON, JR.,

Consulting Engineer and Metallurgist, New York, N. Y.

Third, oxygen seems to act as a brake on the separation of the carbon and to prevent the hard and strong needles of cementite which exist above the last transformation point from breaking down into graphite and ferrite, of which only the latter has any strength at all, and that much less than any other iron-carbon compound. This action is clearly shown in Fig. 28, a

FIG. 20.



Unetched.

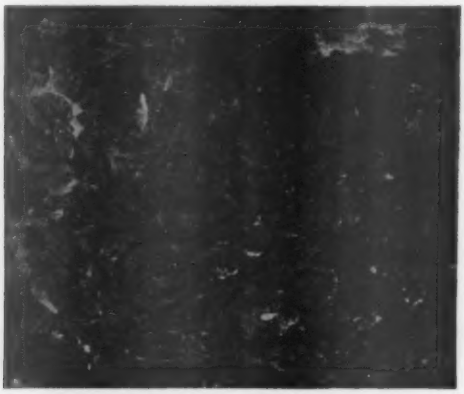
photomicrograph of a coke iron of excellent reputation, exhibiting a number of long, slender plates of graphite with similarly shaped bodies of ferrite on one or both sides of them. These jointly constitute the remains of crystals of cementite by whose breaking down they were formed. The structure is obviously a weak one, not only on account of its shape, but because the graphite

* Presented at a joint meeting of the Philadelphia Section of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of the Institute held Thursday, October 8, 1914.

Continued from page 93, January issue.

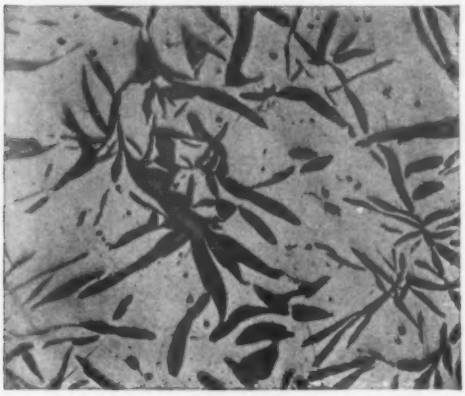
and ferrite are so much weaker than the original cementite. This structure is never seen in irons containing any important amount of oxygen, for the reason that oxygen seems to prevent the breaking down of iron-carbon compounds to a point very far below the

FIG. 21.



Etched. (Magnified 100 diameters.) Good iron. Silicon, 0.70; oxygen, 0.065 per cent. Breaking strength, 1.25-inch bar, 3500 pounds, 4200 pounds.

FIG. 22.



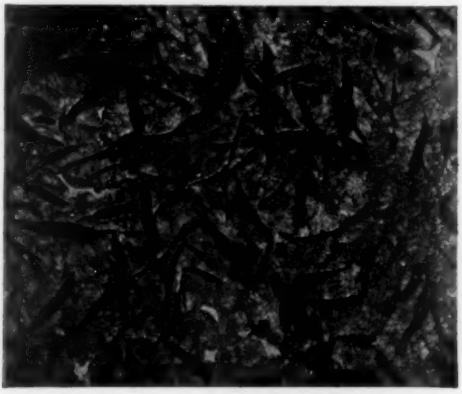
Unetched.

pearlitic ratios of 0.9 per cent., such irons of moderate silicon ranging from 0.6 to 1.0 per cent. combined carbon and seldom containing any visible ferrite. I do not pretend to be able to explain this latter fact, but it is a fact in my own experience, nevertheless. The carbon range given, 0.6 per cent. to 0.9 per cent., is that embracing

the strongest steels, and this fact is undoubtedly of considerable influence in making these irons so strong.

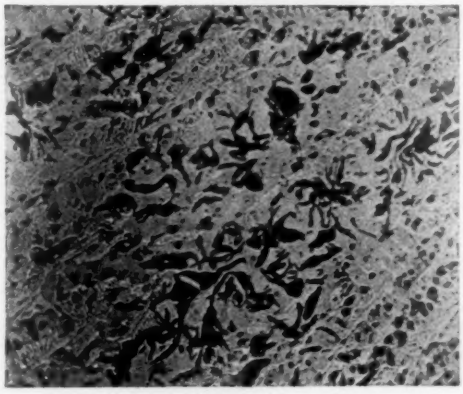
Fourth, oxygen has an effect on a matrix itself, considered as a steel. This, as is known by the best-informed steel metal-

FIG. 23.



Etched. (Magnified 100 diameters.) Poor iron. Silicon, 0.72; oxygen, 0.009 per cent. Breaking strength, 1.25-inch bar, 2500 pounds, 2500 pounds.

FIG. 24.

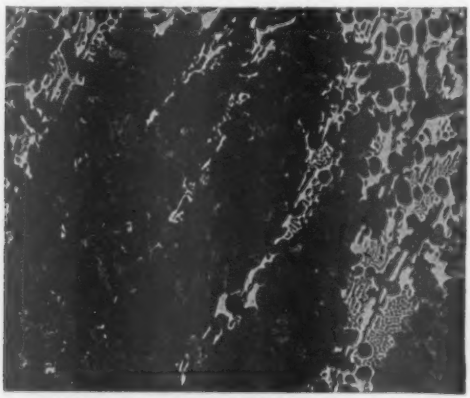


Unetched.

lurgists, is that it strengthens the steel, but reduces its elongation and increases its brittleness. Undoubtedly the oxygen exercises the same influence on the matrix of the iron, but the results as regards brittleness are the opposite of what they are in steel, because nothing promotes brittleness so much as gashes in the

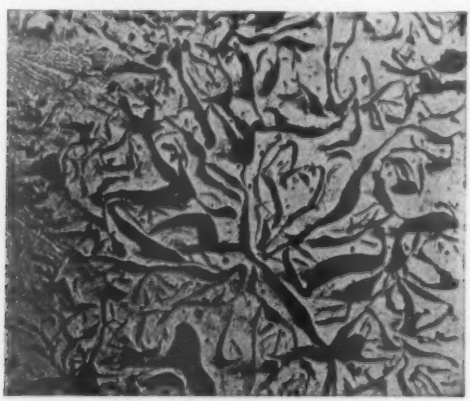
material, such as are caused by flat flakes of graphite, and suppressing these not only increases the strength, but also largely eliminates what might be called incipient cracks, from which breakage might start; and this effect, therefore, reduces the brittleness of the metal

FIG. 25.



Etched. (Magnified 100 diameters.) Remelt. Silicon, 0.70 per cent. Breaking strength, 1.25-inch bar, 4150 pounds.

FIG. 26.



Unetched.

far more than the slight effect on the matrix increases it. As a matter of fact, soft irons containing oxygen have not only greater strength, but also a degree of toughness amazing to those used to only ordinary cast iron; they seem almost to bend before breaking.

Fifth, oxygen exercises also a very important influence on the

chilling power of the iron, due to its retardant action in the separation of the carbon, and it was undoubtedly for this reason that the use of high-grade charcoal iron was formerly almost universal for

FIG. 27.

Etched. (Magnified 100 diameters.) Remelt. Silicon, 0.72 per cent. Breaking strength, 1.25-inch bar, 2750 pounds.

FIG. 28.

Etched. (Magnified 70 diameters.) Coke iron. Note the long, slender bodies of graphite and ferrite side by side, formed by the breaking down of cementite crystals.

car wheels and remains accepted practice to-day for the production of those chilled castings which demand high quality and bring a high price. It seems to be a fact that the presence of oxygen not

only increases the chilling power of the iron, but also increases its sensitiveness to chilling influences. An iron containing oxygen, if cast in sand, will retain somewhat more combined carbon than a similar iron not containing oxygen cast under the same conditions, and if the irons are cast against a chilling surface the one containing oxygen will begin to show a white chill at a higher silicon than the other, and will continue to show greater chill for the same silicon as the latter element decreases all the way to the lowest limits. Moreover, the character of the two chills is quite

FIG. 29.

Unetched. (Magnified 100 diameters.) "Special" charcoal iron, showing finely-divided and almost completely nodular graphite.

different. The chill of the oxygen-free iron is made up of needle-shaped crystals, or rather crystals shaped like long, slender pyramids, with their axes perpendicular to the chilling surface, their sides brilliantly polished, and making sharp angles with each other, so that the crystalline mass has but little strength in any direction parallel to the chilling surface. The chill of the oxygenated iron, on the other hand, shows crystallization normal to the surface. But these crystals, instead of being highly polished,

have rough faces, so that they interlock with one another. The chill shades well into the gray at the base, the mottled area containing little stars of graphite in the field of white. It is impossible to describe in detail, or even to show by photomicrographs, comparative chill structures, but those whose business is the manufacture of high-grade chilled castings have never ceased to use charcoal irons, even though they cost two to three times as much as coke iron of the same nominal analysis, for the reason that, with this iron, they have found by experience they can produce castings of a quality to justify their customers in paying the difference in price.

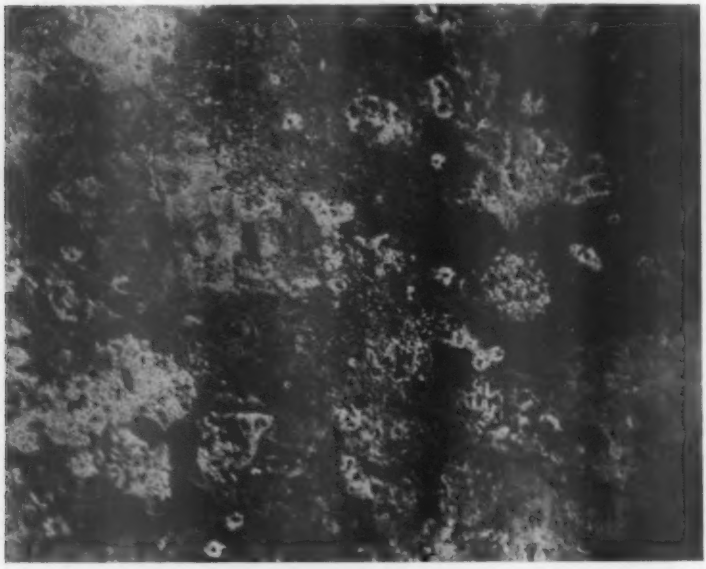
That the difference between charcoal iron and coke is in the carbon and oxygen I have described already, and in those two elements alone we have proved (so far as anything is capable of any absolute proof in so complicated a subject) by analyzing not only for all the common elements, but also the rarer ones and for gases such as nitrogen and hydrogen. Hydrogen we found to be absent, but nitrogen we found to be present in varying quantities, but no variation of the quality of the iron attributable to its variation could be observed, and, while we added nitrogen to the remelts by introducing nitrogenous substances, the differences produced even by considerable additions of nitrogen were unimportant.

Here, then, we find, as has so often been found before, that these curious, one might almost say mysterious, variations of quality arise not from variations of one element, but from simultaneous variations of two. We have variations of carbon from well above to well below the eutectic ratio, with the resulting low quality in the first case; and we have, with this, variations in the oxygen whose presence results in greatly improved quality, whether with high or with low carbon. Considering the complexities of the operation of the blast furnace, the little that we have known until recently about its thermal equilibrium and the variations in the latter produced by different conditions of working, and the effect of these variations on the carbon and oxygen contents of the iron produced, it is not surprising that the variations in the quality of charcoal iron, as controlled by variations of furnace practice, were so difficult of understanding as to seem positively mysterious.

The analysis of the thermal equilibrium of furnaces, to which I have before alluded, shows that those furnaces which produce

good iron run with a relative deficiency of heat in the hearth, while those which produce bad iron run with an excess of heat in the hearth. Observation both by eye and with the pyrometer shows that irons made under the latter condition are much higher in temperature as they come from the furnace than those made under the former, and this leads to two results—elimination of oxygen (which appears to be a function of temperature more than anything else) and super-carbonization of the iron, because while we know but little concerning the conditions which control the car-

FIG. 30.



Etched. (Magnified 100 diameters.) Same as Fig. 29.

bonization of iron, we do know that the degree of saturation possible increases with the temperature. We find, therefore, that those furnaces which work with excess of heat in the hearth tend to super-carbonization and to complete deoxidization, thereby lowering the quality of the iron, both by giving the weak eutectic structure to the matrix and by cutting it to pieces with large flakes of graphite.

In the case of cold blast charcoal iron, we have probably a modified condition of the enormous volume of carbon in the hearth

tending to carbonize this iron more highly than normal, in spite of its low hearth temperature. We have here, then, a condition tending toward fairly high carbon, but also a condition of low temperature favoring high oxygen, and these are characteristic of iron produced by this process. The carbons are not excessive, ranging around 4 per cent. in good, cold blast iron, while the oxygen is the highest in any standard variety of iron produced, ranging in such samples as we have analyzed from about 0.05 to 0.07. These two facts are largely responsible for giving this iron its desirable characteristics, because the presence of oxygen seems to prevent absolutely the excessive graphitization of carbon, even when the carbon contents are high. This seems to be in line with the fact above mentioned, that oxygen exerts a general tendency in the direction of preventing the breaking down of the combined carbon into the graphite form.

Thus, with cold blast iron, we can secure the benefit of a large percentage of cementite in our chilled castings, without the danger of having this break down into graphite, as happens with carbon irons free from oxygen. We are able, therefore, to obtain extremely hard chill along with the extreme closeness of grain and the accompanying physical strength in the gray portion which oxygen brings.

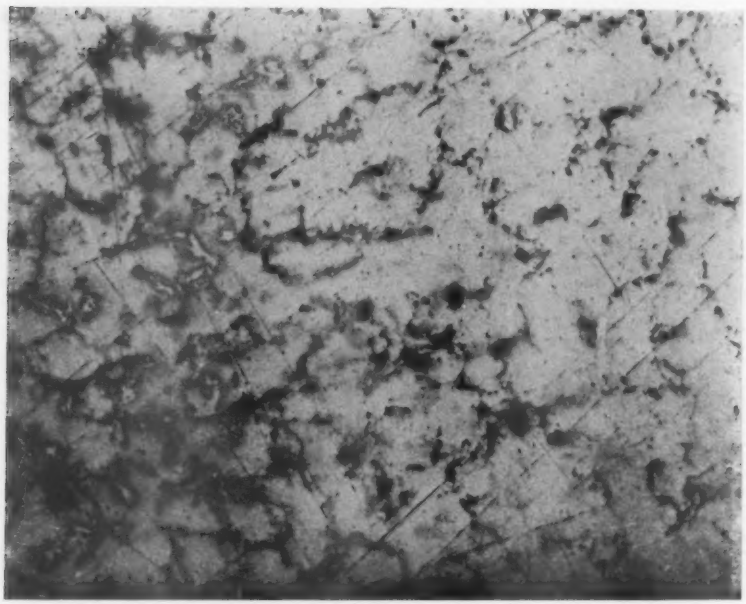
MANGANESE.

Manganese has been praised by many as a panacea for almost all the ills to which the foundry trade is liable, whether from too soft or too hard castings. On the other hand, it has been unhesitatingly condemned by many other able foundrymen as the basis of most of our errors in foundry practice, particularly in the line of chilled castings.

The effect of manganese on steel has been exhaustively investigated (see "Manganese Steel," R. A. Hadfield, *Journal Iron and Steel Institute*, 1888, vol. ii), but, within the limits in which it is used in foundry practice, it is probable that we can largely ignore this effect on the matrix of the iron, on account of its more important collateral actions. These are important, and are two or three in number, and it is certain that the effect of manganese, like that of silicon, undergoes a reversal after it exceeds a certain amount. Manganese has a greater affinity for sulphur than has iron. It is, in fact, a much more active element chemically than iron in all particulars. As a result, it takes the sulphur away from

the iron and forms with it manganese sulphide. It is a general law of metallurgy that a metal will dissolve compounds of itself, but not compounds of another metal with anything like the same facility. In consequence of this law, the manganese sulphide separates out from the iron and rises to the surface. It may be seen doing this in the ladle under certain conditions, and even where it does not separate out completely, manganese sulphide,

FIG. 31.



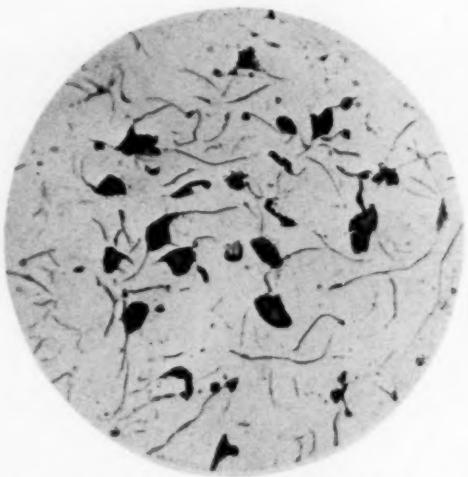
Unetched. (Magnified 100 diameters.) Coke iron-oxygen, same as Fig. 6. (Kindness of Professor Campbell.)

not being dissolved by iron, is much less harmful than iron sulphide, which is dissolved by it with the consequences above described.

The first effect of the addition of manganese is, therefore, to remove a part of the sulphur. The action is not quantitative, and several times the amount of manganese sufficient to form manganese sulphide with all the sulphur present must be added to obtain the removal of much of this latter. The manganese which does not combine with the sulphur combines with the iron, when

molten, in the condition of a double carbide. Manganese, having a higher affinity for carbon than iron, causes an increased absorption of carbon by the metal in the blast furnace, even up to 6 or 7 per cent. in ferro-manganese and up to 4 or 5 per cent, in spiegeleisen containing 18 to 22 per cent. of manganese. The effect of the manganese itself, after it passes 1 or 2 per cent., is to harden the iron, by holding more of the carbon in the combined condition. This increases the strength of the matrix in ordinary gray irons and also limits the formation of graphite. The result of these actions is that manganese strengthens the iron in addition to increasing

FIG. 32.



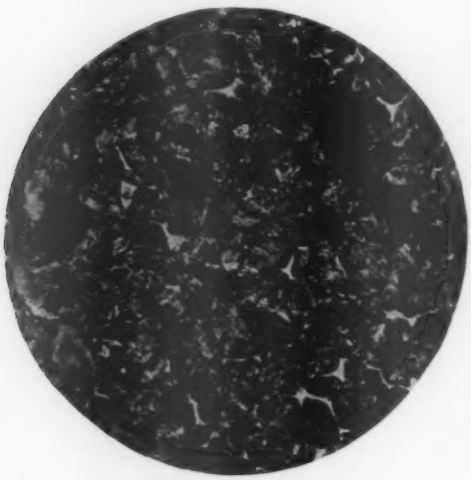
Unetched. (Magnified 100 diameters.) Oxygenated coke iron, showing nodular condition of graphite.

its chilling power, and it is used for this latter purpose to make chilling irons harder, as well as to make soft irons softer. It is obvious, from what has been said, that these actions are the results of two different sets of effects, one of which predominates in the one portion of the manganese range and the other in the other. The objection to the use of manganese for producing chill is that iron containing much of it crystallizes into large, knife-like crystals with extremely smooth faces, so that the end of a broken pig of spiegel often shows crystals sticking out almost like knife blades, and the whole surface is made up of the faces of intersecting crystals with but little cohesion with one another. It is

probably this tendency which gives car wheels, which obtain their chill by the use of manganese, their tendency to "shell out," that is to say, under extra stress, a group of these crystals lose their cohesion with one another, loosen and finally fall out, producing what car-wheel men call a "shell-out." Moreover, the manganese chill is much softer than a straight iron chill, and breaks down under wear.

The activity of manganese as a deoxidizer, as well as a desulphurizer, is well known, and when manganese is added to metal high in oxygen some of this latter oxygen is promptly scoured out;

FIG. 33.



Etched. (Magnified 100 diameters.) Same as Fig. 30.

the chilling power and strength of the metal are thereby reduced. On the other hand, if still more manganese be added, when 1½ to 2 per cent. is reached, the strength of the iron and its chilling power increase, on account of the direct action of the manganese in throwing the carbon into the combined condition, but in the form of flat plates, as I have just explained. This conflicting tendency, in conjunction with its effect in removing sulphur and the powerful effect of that element on the quality of the castings, makes it perfectly evident that the rôle of manganese is an extremely complicated one, but, on account of this powerful deoxidizing influence, it is my judgment that it should be kept low in all castings where the highest qualities, particularly strength,

closeness of grain, and chilling power, are desired, because while these qualities *of a kind* can be obtained by the use of manganese in considerable quantity, the fundamental structure of the iron produced is inherently inferior to the structure produced by the presence of oxygen, and it is a matter of established practice that, in the production of chilled castings, the desired result cannot be obtained by the addition of ferro-manganese alone, as at one time was thought to be the case.

Some manganese, perhaps up to 0.5 or 0.6 per cent., is desirable in cupola melted iron, to hold the sulphur in check, and it may be useful for other purposes in special cases, but for the best castings manganese should generally be kept within very moderate limits. Some of the manufacturers of chilled rolls will not tolerate it above 0.30 per cent.

THE EFFECTS OF TIME.

Before discussing the effect of other elements on the iron-carbon alloys, it might be well to discuss the effects of time. The iron-carbon diagram shows only equilibrium conditions, and the time required for the attainment of some of the equilibriæ shown by the iron-carbon diagram is extremely short, while for others it is very long. Hence the diagram cannot tell us what will happen in any actual case unless the time factor is considered.

The most important effect of time (that is, of the rate of cooling) is its influence on the graphitization of the carbon after solidification. The evolution of graphite during cooling through the molten condition seems to occur only with hypereutectic irons, and this appears to be a function of time, because irons which throw off graphite into the air as they run from the furnace can only be converted into good castings from this initial heat by pouring hot and just as quickly as possible. If poured slowly, the graphite will accumulate at the top of the mould so as to make the whole top of the casting worthless—it will be "worm eaten" at the best, and at the worst may contain great cavities filled with loose graphite flakes of large size. Whether hot pouring simply causes the metal to set more quickly and thus prevent the rising of the hypereutectic graphite, or whether the formation of the graphite is actually prevented, I have never determined, but it is probable that both effects play a part.

In regard to the graphitization after solidification, our knowl-

edge is more definite. In this case all the carbon not thrown out as hypereutectic graphite is combined at solidification, and, if the cooling be rapid from that point, the iron will remain perfectly white. But, if the casting be made to cool slowly, it will not only graphitize, but the graphite may form into very large flakes. The best illustration of this is to be found in the salamander taken from the hearth of the furnace after blowing out. This contains huge flakes of graphite an inch or two in extent, and the

FIG. 34.

Etched. (Magnified 100 diameters.) Salamander. The heavy bands of graphite have completely destroyed the continuity of the structure.

intersections of the flakes cut the iron into irregular solids quite without cohesion, so that a large lump of salamander can frequently be broken apart with the fingers into pieces of small size, each consisting solely of iron and graphite. Fig. 34 shows a microphotograph of such a piece, and shows why this must be so. The iron in this case has remained just below the melting-point for several years.

From this point of view, the action of chilling becomes ex-

tremely simple. We merely shorten the time of cooling through the range in which graphitization could take place so as to prevent or diminish this action and leave the carbon in the combined condition. The surface next the "chiller" is the whitest and hardest, because its heat is removed instantly, while the metal back of it has to be conducted through the chilled surface and also through the warmed face of the chiller into the cold metal behind it. This is obviously a much slower operation, and, as a result, more graphitization can occur in the metal behind the chilling face.

In the same way, if the chiller be too light in proportion to the body of the metal to be chilled, a very insufficient chill will result, because the thermal capacity of the chiller is only sufficient to absorb the heat from a thin zone of the molten metal, and this is promptly heated up again by the larger body of molten metal behind, which "draws" the chill already formed, exactly as a blacksmith draws the temper of the quenched edge of a tool.

Silicon and time, then, are seen to be the principal factors making for graphitization, while oxygen, sulphur, and manganese are the principal ones resisting it. Of these three, manganese is hostile to the other two, and, if present in sufficient quantity, destroys their effect, while its own effect does not alone give a chill of the character desired. Sulphur gives a hard chill, but an essentially brittle and unreliable one, accompanied by high shrinkage and weak structure back of the chill. Oxygen gives a tough, hard chill, low shrinkage, and the strongest and best structure back of the chill.

THE LESS COMMON ALLOYING ELEMENTS.

Chromium.

The effect of chromium on iron and iron-carbon compounds has also been extensively investigated by Sir Robert Hadfield.[2] The effect of chromium is to harden the matrix of the iron, making an intensely hard but very brittle double carbide of chromium and iron. In low carbon alloys this makes a very strong, hard steel of low elongation. When the metal contains enough carbon to constitute cast iron, the tendency is to throw more and more of it into the combined condition, until, at 3.0 or 4.0 per cent. chromium, the metal is entirely white, the fracture being flat, shining, highly polished plates, very similar to those in spiegel, and to

[2] *Journal of the Iron and Steel Institute*, 1892, vol. ii.

those of weak iron carbon eutectic previously illustrated. (Compare Fig. 35, showing chromiferous iron, with Figs. 3 and 4, showing weak, high carbon, spotted iron.)

There is no doubt that chromium strengthens iron by throwing the carbon into the combined condition and by closing up its grain. It enables a hard chill to be secured, even in spite of the influence

FIG. 35.

Etched. (Magnified 100 diameters.) Chromiferous pig iron. Note similarity to eutectic structure of (mesh) spotted iron, Figs. 3 and 4.

of a considerable percentage of silicon; but the structure consisting of these laminated plates has not the staying power of a chill produced by oxygen content without any other substance.

Fig. 36 shows a strong charcoal iron remelted in a crucible with sufficient chromium to raise the content of the remelt to 4 per cent. The structure to which I have alluded is strikingly shown. Test bars made from this mixture were strong, but not by 20

per cent. as strong as test bars made from high oxygen iron without such a mixture. Chromiferous iron, particularly a natural alloy made from certain ores, which contain chromium and nickel to the extent of about 2.5 and 1.25 per cent. respectively, has been urged, in the past, as a substitute for the best grades of charcoal iron. It has only been moderately successful, however, in meeting the claims made for it. It would seem that it is impossible for this alloy to equal the product which I shall presently describe, since this product is far superior in quality to charcoal iron.

Nickel.

Nickel seems to be one of the few metallic elements which produces a truly beneficial effect on the character of cast iron. Its highly beneficial effect on steel has long been understood, but this effect does not begin until the amount of nickel exceeds 3.0 per cent. Beneficial results are derived by its presence in cast iron to the extent of only 1.0 or 2.0 per cent. It strengthens the iron and improves its chilling power, without appearing to cause any lamination or other objectionable features. These statements are based solely upon some experience made at Ashland by remelting irons in the crucible with nickel sufficient to give the above-mentioned percentages, and it would be unwise to generalize too widely on such limited data.

It is, of course, not to be overlooked that the expense of nickel for treating cast iron is almost prohibitive. One per cent., or 22 pounds, would increase the cost about $7 per ton, and that consideration, taken in conjunction with the fact that even nickel is not able to produce results as good as those obtainable with the new kind of iron presently to be described, makes this an unprofitable field for further research.

For strong, tough irons with hard, wear-resisting chill no material has apparently been developed as good as an iron containing as much oxygen as its silicon content will permit.

Titanium.

The effect of titanium on cast iron is a much-discussed question, and not nearly so much experience is available for the solution of it as in the case of manganese, but the probabilities are that the action of this alloy has also very contradictory effects, on account of its action on different elements.

An extensive paper on the subject was published by Professor Bradley Stoughton before the American Institute of Mining Engineers in 1912, but the results recorded as to the effect of strength of cast iron, etc., were rather contradictory. One thing, however, seemed to stand out very clearly, and this was that titanium reduced the chill. This is in accordance with what we should expect, for titanium is one of the strongest deoxidizers known. It also has a very high affinity for sulphur and nitrogen. Such effect as ni-

FIG. 36.

Etched. (Magnified 100 diameters.) Pig iron with 4 per cent. chromium. Note flat crystals and compare with Figs. 3 and 4, "spotted" (poor) charcoal iron.

trogen has is undoubtedly in the direction of producing chill, and therefore, the effect of titanium would tend to remove three elements producing chill, namely, oxygen, sulphur, and nitrogen. This amply explains why the chill is reduced, and probably explains also why the results on strength are so contradictory. The titanium removes the highly beneficial oxygen, and it also helps to remove the detrimental sulphur.

The reduction of chilling power which is admitted by advocates of the use of this alloy for cast iron requires the use of more man-

ganese for its restoration, and this is highly objectionable, for reasons already pointed out, and it seems extremely doubtful that any benefit will be found by prolonged experience to result from the use of titanium in cast iron, even in spite of the fact that its action on the matrix of the iron itself may be to strengthen it. Its influence in removing oxygen in good castings is extremely detrimental, and this is probably not offset by any other beneficent action which it may have, while where particularly good castings are not required there is no call for the use of any treating material whatever.

Vanadium.

Following the general custom of claiming a beneficial action on cast iron for any alloying material which has been found useful in steel manufacture, traces of vanadium have been claimed to have a beneficial effect on cast iron. Vanadium, like titanium, is a powerful scavenger. Its best-informed advocates claim that its principal service is not in remaining in the steel itself, but in going out of it with the oxygen, nitrogen, etc., which it removes.

This is exactly the same effect as that produced by titanium, and it seems almost certain that vanadium will be found objectionable in good irons containing oxygen, as it has already been found to be without benefit for ordinary castings not containing that element.

Great claims have recently been made for irons containing traces of this element, but the photomicrographs used to illustrate the claims did not display a particularly meritorious structure, and the results of the physical tests given were so far below the results obtainable with irons containing oxygen as to be beneath comparison with them.

As a result of this review of all the metals that are claimed to benefit cast iron, we see that most of them, with the possible exception of manganese, have based their principal claims on being deoxidizers, although some also have merit as desulphurizers, and some have a direct effect in throwing the carbon into the combined condition.

We have already seen, and I trust that I shall be able to show still more clearly presently, that oxygen is of greater benefit to cast iron than any other element at our disposal, with the exception of silicon, and that any addition to the iron which tends to

remove oxygen is not beneficial to it, but is highly objectionable, the accepted theories to the contrary notwithstanding.

We have seen, by unmistakable evidence also, that, while some of these metals tend to throw the carbon into the combined condition, the form into which they throw it (or rather the type of crystallization which they induce) is an extremely objectionable one, being inherently weak and brittle, and that the sole benefit which we can expect from the use of these metals is the removal of a portion of the sulphur, for which a small amount of manganese seems to suffice—at least to the extent to which such removal is possible. When this result is accomplished with manganese in moderation, the strength of the iron is not materially impaired, though its chilling power, in the judgment of some expert users, is decreased after the manganese increases above 0.3 per cent.

It seems safe to say, therefore, that, if it were not for sulphur, the more perfectly we dispensed with any of these alloying metals the better iron we should obtain where strength, close grain, and strong, hard chill are the qualities desired.

Remember now the demonstrated fact that the old-fashioned cold and warm blast charcoal iron contained much oxygen, and you will understand that the conscientious founder, in his insistence on the use of these materials for high-grade chilled castings, was not actuated by prejudice and ignorance, but by a profound knowledge of his subject, even though he could not explain the reason for the results produced.

It will be clearly recognized that this is a flat contradiction of the tenets of theoretical metallurgy, but we find it necesary in every science to recognize, from time to time, the fact that we have taken a wrong trail and are being led from, not toward, our goal, and the only thing to do under such circumstances is to leave that path and take up the correct course, even though we have to retrace our footsteps in doing so.

A critical examination of the basis of the old theory will disclose the fact that the amount of real evidence on which it rested was small. No work of any amount in determining the actual oxygen present in cast iron by the combustion method has ever come to my attention, except that which we initiated at Ashland, and, while some work has been done by solution of the iron and determining the residual oxide, this method cannot receive much consideration on account of the vast possibilities of oxidation during solution.

It is true that there is a vast amount of inferential evidence available to the careful observer that oxygen produces a difference. I was convinced that there was oxygen in some iron ten years before I had obtained any determinations of that element, and the results of the subsequent determinations have shown that I was right, but, because the iron produced was for steel-making purposes, and, when high in oxygen, was generally high in sulphur also (and therefore rejected by the steel works), I considered the effect of oxygen harmful. This was a coke iron, and when I first saw the " special " charcoal iron I condemned it as worthless, because of its strong resemblance to this high oxygen coke iron. The introduction of the testing machine soon showed the complete fallacy of this judgment.

On the other hand, much has been said as to the burning of iron by overheating it, and its poorer quality when overheated has been attributed to the introduction of oxygen, especially in air-furnace work. The explanation will work just as well if turned the other way around. When metal is overheated in the air furnace the oxygen, of which that apparatus introduces a little, reacts with the silicon or carbon, or both, and goes out, weakening the iron and impairing its quality, just as the exponents of the " burning " theory contend.

The fact that increasing temperature promotes the elimination of oxygen is proved by several facts. The " Experiments on the Overoxidation of Steel " carried on by Messrs. Shimer and Keachline, and reported by them in a paper before the American Institute of Mining Engineers, showed that, as the temperature went up, less oxygen stayed in. These investigators found less oxygen in steel with only about 1.0 per cent. carbon and no silicon than we find in cast iron with 3.5 per cent. carbon and 1 or 2 per cent. silicon, because the temperature of molten steel is some five hundred degrees higher than that of cast iron.

In the course of my own experience, I have seen a heat in a small converter purposely blown cold until the silicon was removed, but most of the carbon left in. This metal was alive with oxygen. It was exceedingly " wild " when hot, and when cold it was so full of blowholes as to have no strength whatever. The same iron, blown hot, yielded steel of a very high temperature, containing only about 0.06 per cent. carbon, and was absolutely quiet, even before the addition of the deoxidizers, and poured like cream.

All these facts agree with the well-established general law that the affinity of carbon for oxygen increases very rapidly with the temperature. You will see then that, while the view I am offering you is opposed by an accepted theory, it is supported by a vast array of established facts.

In spite of the volume of evidence which we have accumulated, and which I have set forth in the published paper above mentioned, I am well aware that it would be impossible for many to accept my conclusions on this evidence alone. I shall pass, therefore, to the second stage of my subject, namely:

THE PRODUCTION OF AN IRON HIGH IN OXYGEN AND THE CHARACTERISTICS OF SUCH AN IRON.

When I had obtained what seemed reasonably valid testimony that oxygen was the cause of the good qualities in charcoal iron, I began to experiment with methods of introducing it at will by different ways of operating the furnace, and also by introducing hot ore, mill scale, etc., into ladles and then filling the ladles with iron as it came from the furnace. This yielded no useful result.

After I had left the charcoal iron business I began to investigate further the conditions under which silicon and carbon were removed from iron during its conversion into steel, in order to obtain a method of introducing oxygen into iron at will without lowering the carbon. I found from the steel men that by starting with a very hot heat in the Bessemer, they could blow the carbon out to a very considerable extent before the silicon was gone, while with a comparatively cold initial heat the silicon would practically all disappear before the carbon began to be removed. Moreover, it seemed perfectly evident that the reason I had been unable to get oxygen into normal irons, either in or outside the furnace, was because, at the temperature at which I was working, the activity of the silicon and that of the carbon were such that they instantly removed the oxygen. It is, of course, no trouble to resiliconize a bath of metal, and therefore it seemed to me that if I could take metal and reduce it to the condition of the spongy white iron, which we obtained from the furnace when it was so cold as to be almost chilled, and could then mix that with normal iron high enough in silicon to give the resulting mixture the desired silicon contents (all the while keeping the temperature as low as possible),

I should reproduce, outside the furnace, the conditions which had existed inside it, always providing that the temperature was kept low enough, because observation of converter practice had convinced me that 0.05 per cent. carbon was more efficacious in removing oxygen at 3000° than was 3 per cent. at 2300°. Accordingly, therefore, I had preliminary tests made at a steel-casting plant. A heat of metal of 1.0 per cent. silicon was blown in the side blow converter, holding the temperature down by stopping the blow and turning down the heat several times. The blow was continued until the carbon flame began to break through, showing that the silicon was gone and the carbon was beginning to go. The blow was then stopped and the vessel turned down. The sample of metal taken from it at that time was, when cold, a white iron full of blowholes, rotten, brittle, and worthless to the last degree. With this was then mixed an equal volume of 2.0 per cent. silicon iron direct from the cupola, and from that mixture test bars were cast. Test bars had also been cast of the original metal, both the 1.0 per cent. silicon iron and the 2.0 per cent., and these broke at approximately 2300 pounds on 1¼-inch round bars on 12-inch centres. Similar bars from the treated metal broke from 4000 to 4300 pounds.

Steps were then taken to obtain patents on this process, and you will well believe that, in view of the current opinions in metallurgy, there were but few citations from the Patent Office of anything of a similar nature. On the contrary, the patent examiners found my statements and claims so utterly at variance with all the accepted theories on the subject that they were inclined to consider me a victim of self-delusion. However, we had at hand a mass of evidence, and when it was presented to them they became convinced that, while there was a conflict between the accepted theories of metallurgy and the facts, it would be better to give precedence to the facts, and let the accepted theories go, and they allowed the patents in their broadest possible form.

After this a number of furnace companies were approached, with the view of having them undertake the manufacture of the new metal, and, unless one had experienced it, one would not believe with how little enthusiasm the proposal was received. Finally I went to Mr. E. A. S. Clarke, president of the Lackawanna Steel Company, and he asked me to go to Buffalo to see those in charge of the company's plant there, at the same time accompanying his

invitation with intimations of the skepticism of all parties in regard to my process and the results claimed for it. When I reached Buffalo this skepticism was made even more evident and put in more direct language, but when I showed them the experimental results which I had obtained at the steel-casting plant they waived their doubts for the time being, and consented to make a trial of the process. At the first attempt, the conditions were not altogether favorable. A plant laid out for the production of steel, with no idea of ever desiring to oxygenate pig iron, may obviously not be ideally arranged for the latter purpose, while blowers, familiar with the necessity of getting a high temperature to produce good steel, found it difficult to blow a heat as cold as possible. Moreover, the iron which was used to mix with the blown metal was lower in silicon than we had expected to get, and this resulted practically in a " mottled " iron. All these conditions militated against the success of the trial. Nevertheless, test bars, made from the metal after treatment, showed an increase of about 20 per cent. in strength over the original iron even after remelting, and the Lackawanna Company then felt justified in making another test and arranging the conditions more in accordance with the requirements of the operation. At this second test we provided a metal of about 2.5 per cent silicon to mix with the blown metal. The phosphorus was also increased so as to give a result comparable to foundry iron. The metal to be blown was taken from the mixer, and was mixed half-and-half with the high silicon metal, and test bars 1¼-inches round and 2-inches square were cast from the mixture to determine the strength of the iron before treatment. After the converterful of mixer metal was blown the high silicon iron was added, and additional test bars were made from this mixture. The 1¼-inch round test bars of the original untreated metal broke at about 3100 pounds average; high silicon metal, and test bars 1¼ inches round and 2 inches centres. Of the treated metal, the 1¼-inch test bars broke at about 5100 pounds average, and the 2-inch square test bars broke at 22,900 pounds average. The 1¼-inch test bars were a little over size in each case, but about the same amount in each, so that the results are comparable. By a curious coincidence, the increase in strength, based on the average of all the good bars, worked out to exactly 70 per cent. in both cases. Since that time other heats of other silicon have been made, and the strength is in all cases well above 20,000 pounds on the 2-inch square bar.

The first questions you will naturally ask are: Does the oxygen stay in this iron on remelting, and, if so, why? Why do not the carbon and silicon which are present scour it out, and restore the iron to its normal condition?

The answer to the first is the important one from the commercial point of view, and so soon as we have obtained these results we put some of the iron produced through a cupola as a separate charge. When it came out we raised the silicon with ferro-silicon from 1.26 to about 1.50 per cent. so as to make it comparable with ordinary iron from the cupola. Even after this treatment with ferro-silicon, which tended to deoxidize it and also to throw out the carbon into the graphitic condition, the strength remained at 21,000 pounds. We had previously demonstrated, by an extensive series of remelts of charcoal iron in crucibles, as described in the paper above mentioned, that the oxygen did remain, and that, as I have already stated, an iron which went into the crucible strong came out of it strong. The actual presence of the oxygen after remelting, as well as before, was determined by analysis before and after the results.

The reply to the second question seems at first sight more difficult, but it is not really so. It seems to be a perfectly general law of chemical action that, while reactions go on in concentrated solutions along certain lines and proceed at least nearly to completion in such solutions, in dilute solutions the same law does not hold. Take, for instance, the case of manganese and sulphur. You know very well that iron sulphide is broken up by manganese; the sulphur is seized and forms manganese sulphide, leaving the iron, and the manganese sulphide then leaves them both. Now, if this reaction proceeded to completion, it should be easy, by adding an excess of manganese, to take out *all* the sulphur. But, as a matter of fact, you are perfectly well aware that this is entirely impossible; that each unit of sulphur is harder to remove than the last; and that you reach a point beyond which the addition of further manganese does not reduce the sulphur at all. I take the same to be the case in regard to oxygen, only that the equilibrium point is lower and the influence of temperature is more important, so that, if the temperature be kept moderate, the oxygen will remain to some extent, unless powerful deoxidizers are added.

In this connection I may say that we had an accidental confirmation of the correctness of the oxygen theory, which may not be

without interest. By accident, one heat of the new metal was made with iron about 3.0 per cent. in manganese, so that the resulting mixture was about 1½ per cent. The strength of this iron was reduced 3000 pounds,—*i.e.*, from about 21,000 pounds to about 18,000 pounds,—on the 2-inch square bar as compared with iron identically the same in all particulars, except that the manganese was normal, or about 0.4 per cent.

There are two other questions of interest:

First.—In what respect and for what reason is this new material better than the so-called semi-steel (cast iron with a mixture of steel scrap)?

Second.—How do we achieve the advantage of high carbon, which, it is my belief, is one of the advantages of cold-blast charcoal iron for special purposes?

The answer to the first may be divided into four portions:

(*a*) The effect of oxygen is to reduce the graphite to a fraction of its injurious area, by changing its shape. This is obviously far superior to a simple dilution of the carbon, which can only reduce the graphite by about a third in the most extreme case.

(*b*) The temperature required for the melting of steel scrap is very high, materially above that of an iron with normal carbon. This requires such iron to be raised to a higher temperature than iron with normal carbon, and facilitates the elimination of any oxygen which it may contain.

(*c*) The use of steel scrap dilutes the carbon and reduces the quantity of cementite which can be formed, so that chilled castings made in this way have not the hardness and wearing qualities of those made of irons with high carbon when the latter is all combined.

(*d*) It seems certain that carbon in proper condition facilitates the machinability of an iron, remembering that this carbon is in the form of graphite, one of the best lubricants known. It has been demonstrated by experience that an iron of a given strength of matrix machines more easily if it contains more carbon, without necessarily being weaker than low carbon iron if the carbon be in more nodular form than that in the low carbon iron.

The answer to the second question is that, by the hot operation of coke furnaces with a limy slag, the carbon can be forced up to or beyond 4 per cent., and by proper operation in treating it we can preserve practically all this carbon, thereby securing an amount

equal to that of the cold-blast iron. Whether we shall be able to go beyond this, and introduce additional carbon during or after the treatment, I am not able to say, because we have made no experiments along that line. It seems likely that this will be unnecessary in practice, for most of the users of cold-blast charcoal iron use it in the air furnaces, and reduce the carbon to between 3.5 and 3 per cent. before casting, an amount which we can easily exceed.

We have had a number of tests made by parties who were interested in the purchase of iron. Some of these I am not at liberty to publish, but the representative of one large railroad company has told me privately that it found the strength and chilling power of the iron to be virtually the same as that of one of the famous brands of Eastern charcoal iron. Another railroad company reported that it found the breaking strength of the iron in 2-inch square test bars on 12-inch centres to be 25,000 and some odd pounds; while through the kindness of Mr. Harry B. Swan, of the Cadillac Motor Car Company, I am able to present a table of results of crucible remelts made from this iron.

CADILLAC RESULTS.

Analysis	Combined carbon	.85
	Graphitic carbon	2.65
	Manganese	.26
	Phosphorus	.326
	Sulphur	.039
	Silicon	1.25

The test bars showed the following results from the Standard 1¼-inch round bar of the American Society of Testing Materials, on 12-inch centres (four bars gave the following results):

	A	B	C	D
Transverse strength in pounds	4,505	4,825	4,825	4,875
Modulus of rupture, pounds per square inch	67,300	67,100	67,100	66,400
Tensile strength, pounds per square inch	34,800	33,800	34,100	33,800
Brinell hardness	202	207	202	196

Charcoal iron showing above 3000 pounds on the 1¼-inch test bar is strong enough to be put into a class of special iron by itself,

while one of 4000 pounds strength is very rare. You will see that this iron is about 60 per cent. stronger than the former, and about 20 per cent. stronger than the latter. The closeness of its grain you will see from the samples and from the photomicrographs (Figs 28 to 31). These latter also show the graphite in this iron to be almost completely nodular, rather than of the flake variety, and show, in the most unmistakable manner, why the iron must be stronger than an iron the same matrix, but with wide flakes of graphite. The effects of oxygen in changing the form of crystallization and in preventing the breaking down of the combined carbon are the same in this iron as they are in charcoal iron, except that worm-blast charcoal iron contains only from 0.015 to 0.30 per cent. oxygen, whereas we have no difficulty in obtaining 0.050 to 0.70 per cent oxygen, with correspondingly greater effect in these two directions.

The experiments which have been made on actual castings show also that the suppression of the eutectic is more than a scientific hypothesis. One large company found that a certain casting was extremely difficult to make of ordinary iron without having shrinkage cavities along a certain line, but that, when poured from this iron, the castings were absolutely sound at this point. This I believe to be because the iron solidifies all at once as a homogeneous mass instead of passing through a long range of progressive freezing. The last freezing or eutectic portion is that which is altered by the presence of this minute quantity of oxygen into something else with a higher melting-point.

Returning now to the iron-carbon diagram, a valuable suggestion has been made by Professor Campbell, to the effect that there are shown by Fig. 2 several paths along which iron-carbon alloys may pass in cooling; that one of these may result in one structure and another in another, and that the presence of a small quantity of oxygen may be the controlling factor which forces the cooling to take place according to one of these paths or another. This suggestion, combined with the diagrams of Guertler and Upton, goes further to account for the facts as we found them in practice than any other that has been made. The suggestion from Upton, that graphitization occurs on one side of the eutectic point below the eutectic freezing temperature and not on the other, is very much in line with the observations of practice, for it is a fact that certain irons will throw off graphite into the air in great pro-

fusion while running from the furnace, whereas other irons of similar composition and perhaps even higher in carbon will show no such tendency whatever. This is particularly true in relatively low carbon coke irons of about 1.0 per cent. silicon and relatively high carbon charcoal irons of about the same silicon. The latter scarcely ever makes any show of graphite as it runs from the furnace. The other fills the cast-house until it looks as though a black snow-storm were in progress.

You will now ask the practical questions: Granted that we have here a new material, what is it good for? What can we do with it?

The answer is that it is good where strength, closeness of grain, steam tightness, and wearing qualities are desired. Above all, it is good where chilling power under strict control and hard, strong chill are desirable. Because irons containing oxygen have this peculiarity, they not only begin to show a chill at a higher silicon percentage than do coke irons, but they are also much more sensitive to chilling influences. High oxygen iron of 1.25 per cent. silicon will show no more white chill than a coke iron if cast in sand, though, of course, it will be much finer grained. But, if cast against a chilling surface, it will show from ⅛ to ¼ inch white chill, whereas when coke iron reaches the range of silicon within which it will "take a chill" it is with difficulty prevented from chilling, even when cast in sand. With this great strength, with this power of making intricate castings without shrinkage cavities, and with its chilling power under accurate control, it seems that the metal should find its largest field, measured in tons, in car wheels, and tests of it for this purpose are now under way. Outside of that field, the metal is particularly adapted for steam, gas, or ammonia cylinders. As a substitute for or improvement on "gun iron" for strong castings, such as are now made from the air furnace, I believe that this metal cast from the cupola will find a large field of usefulness.

It is our hope, also, that with this metal it will be possible to produce malleable castings by melting in the cupola as easily as to produce them from the air furnace, as is done in present practice, because we can supply the carbon of any amount desired, and we can also introduce the oxygen, which it is largely the function of the air furnace to put into the iron now. This statement may seem radical, but I have had made an

analysis of malleable iron, and found it to contain 0.13 per cent. oxygen. Moreover, malleable iron, which under the microscope is shown to be composed of iron interspersed with little round nodules of graphite or temper carbon, is only a step beyond the metal which I have shown you, and, in my judgment, the new metal will eventually be found to constitute an intermediate step between malleable iron and ordinary cast iron. In malleable iron the carbon is all retained in the combined condition, as in cast, and is subsequently graphitized against the resistance of the solid iron by prolonged annealing. The new metal delays graphitization until the structure is sufficiently solidified to resist the formation of the graphite, the resistance being sufficient to force the latter into the forms entirely similar to those in true malleable.

Where castings are made from the maximum percentage of cheap scrap with the minimum of new iron to carry this, a softener is needed, probably in part because of the high sulphur of the mixed scrap; and as this new product tends to produce high combined carbon, and is a strengthener (and to that extent a hardener), it is not recommended for such castings. On the other hand, where a high silicon strong iron is needed, so that it may have good machinability and lend itself to rapid manufacture and yet be strong and fine grained when finished, the ideal material to give these qualities can be made by the new process, and, once the exact combination of strength and machinability desired by the foundrymen is known, that combination can be repeated under conditions of strict control to an extent not possible with any other product.

Iron from the blast furnace has to be taken as produced, not only in oxygen but in the other elements, but, by the use of a mixture of known components, in combination with this process of treatment, we are able to produce iron not only of a given analysis, but with certain physical qualities accompanying that analysis, a degree of control impossible to obtain in iron direct from the blast furnace.

DISCUSSION.

Professor A. E. Outerbridge, Jr., chairman of the meeting, after having invited discussion of the paper of the evening, gave informally a *résumé* of various investigations that have been made by eminent scientists on the condition of carbon in iron. He said that pure carbon is known in several allotropic forms; thus

we have in the diamond the most pellucid and hardest of all crystalline substances. Ordinary lampblack (also pure carbon) is the most opaque substance known to rays of light. Graphite is still another form of carbon, differing in many ways from the other well-known forms. Ordinary cast iron contains from 3½ per cent. to 4 per cent. of carbon; this is usually partly combined with the iron and partly graphitic, the relative proportion of each determining, in large measure, the physical properties of the metal, subject, of course, to controlling influences exerted by silicon, manganese, and other elements.

When white cast iron (a metal having nearly all of its carbon in the combined form) is subjected to a very high temperature for many hours the carbon gradually separates from its combination with the iron and becomes " free " carbon, but examination shows that this free carbon is disseminated throughout the iron in much smaller particles than the flaky, graphitic carbon of ordinary cast iron, and it has been christened " Ledebur's temper carbon," to distinguish it from the free carbon naturally existing in cast iron.

There is a vast difference in density, strength, homogeneity, and ductility between ordinary cast iron containing, let us say, 3½ per cent. of free carbon and annealed white iron containing about the same amount of temper (free) carbon. A cubic foot of this annealed iron will weigh fifty or sixty pounds more than a cubic foot of ordinary gray cast iron.

The tensile strength is at least 50 per cent. greater, the metal is much more homogeneous, and it is to a considerable degree malleable. Ordinary grey cast iron will continue to increase in cubical volume (or " grow ") after repeated heating and cooling to the extraordinary extent of 50 per cent. or more. White cast iron converted into grey iron by heat treatment will not increase in bulk sufficiently to overcome the original shrinkage of the metal in passing from the liquid to the solid state after repeated heating and cooling.

The foregoing facts are mentioned here for the reason that Mr. Johnson claims that the carbon in his iron that has been partially refined by a pneumatic process is distributed in small balls instead of in flakes, as in ordinary cast iron, and may serve to show that there is nothing inherently opposed to experience in his statements in this respect.

Furthermore, we know that when steel or wrought iron scrap is melted with cast iron in proportions ranging all the way from 5 per cent. to 30 per cent. or more we obtain a metal which is exceedingly dense and strong; the free carbon is evenly distributed in very small particles, providing there is sufficient silicon present to prevent the permanent combination of the carbon and the iron. Sterling's "toughened cast iron," patented in England in 1848, was produced by melting wrought iron scrap with cast iron in a cupola. In recent years this metal has been incorrectly called semi-steel." The carbon is distributed throughout the iron in very fine particles.

About twenty years ago Wahl and Greene lined some ladles with powdered hematite ore, into which they poured molten, soft cast iron having tensile strength of about 20,000 pounds per square inch when cast in bars 1 inch square section 15 inches long. Violent ebullition occurred with the formation of slag, caused by the oxygen uniting with the carbon silicon and other oxidizable elements in the iron.

The slag was skimmed off and the metal poured into similar test bars; these were turned and pulled, showing tensile strength of more than 30,000 pounds per square inch. The metal was exceedingly fine grained, dense, and much harder than the same iron untreated.

Some experimental castings were made from this treated metal, and all contained blowholes, attributed to the presence of dissolved iron oxide. No practical use was made of this method of changing the character of molten cast iron, so far as I know. Whether Mr. Johnson's method of burning out silicon and then restoring that element to cast iron will prove successful or not in practice, in producing coke iron of quality superior to charcoal iron, we are, nevertheless, indebted to him for an interesting and valuable paper on the subject.

MR. H. V. WILLE (*Metallurgist, The Baldwin Locomotive Works*): Mr. Johnson appears to have produced a coke iron having characteristics similar to a charcoal iron. It is generally admitted that a charcoal iron has superior chilling qualities and has greater strength than a coke iron. The carbon in the form of charcoal appears to be more soluble in liquid iron than carbon in the form of coke, and there seems to be a further effect; that is, a greater amount of the carbon remains in solution in the charcoal iron during the process of cooling. Therefore the

resultant casting or test-piece has a high percentage of combined carbon, and is, consequently, of greater strength than the usual accepted theory, and maintains that the shape, condition, and even quantity of the graphite crystals in an iron are affected by the amount of oxygen present. Personally, I cannot reconcile the presence of free oxygen with such powerful deoxidizing agents as free carbon, silicon, manganese, vanadium, or titanium. It seems to me that the process proposed by Mr. Johnson is largely a purifying process, and by means of this process he secures an iron having

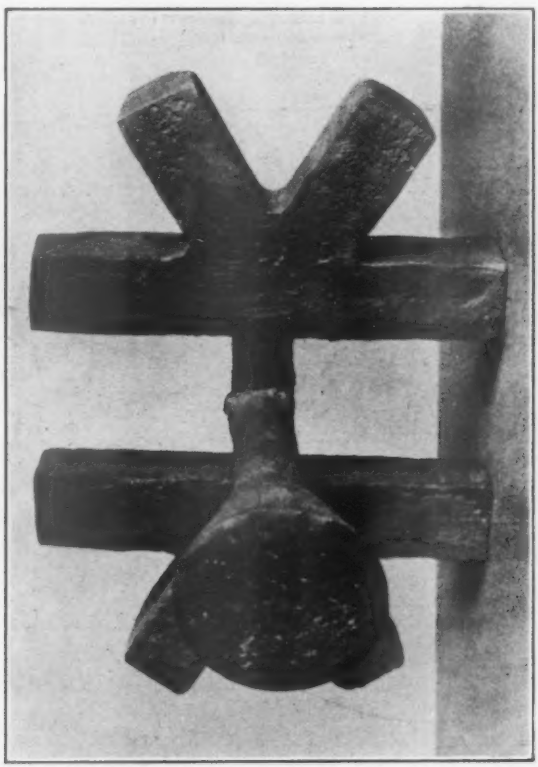
FIG 1.

low sulphur with relatively low silicon. He removes the silicon and, no doubt, a considerable quantity of carbon from a portion of the iron, and then adds to this semi-purified iron an additional coke iron. Mr. Johnson, however, controverts this generally quantity of blast-furnace iron, so that the resultant iron has a comparatively low silicon and low carbon, and it necessarily is a harder and stronger iron than a straight blast-furnace iron. It seems to me, however, that the time to purify an iron should not be after it leaves the blast furnace, for the results of such purifi-

cation will no doubt be greatly modified by melting the iron in a cupola in the presence of large quantities of coke and limestone, It would be better to purify such iron after it leaves the cupola and immediately before it is poured into the mould.

As a result of some experiments which I will later describe, at my suggestion Mr. Carl Hering treated cast iron in an electrical

FIG. 2.



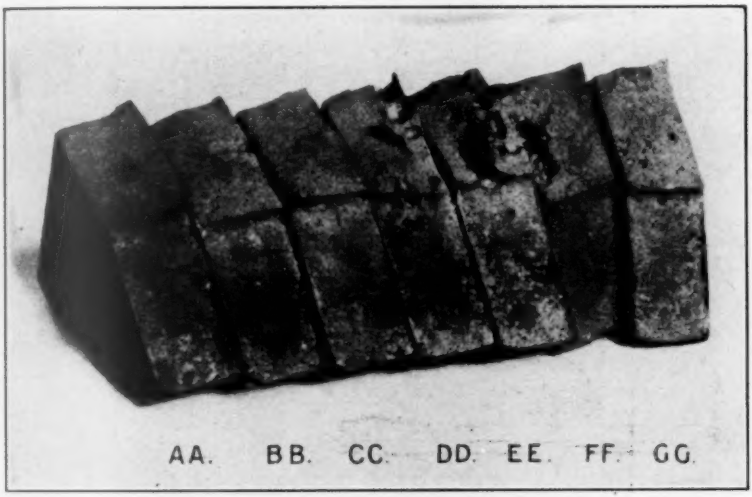
furnace, with the result that the product was much harder, stronger, and denser than an ordinary cupola iron. We also experienced the same results with iron melted in a tilting open-hearth furnace at the Standard Steel Works. This iron was extremely hard and close grained, showing that any purifying process, or any process which will reduce the silicon or carbon, will result in a harder iron. These experiments indicate that it

is not necessary to accept the oxygen theory in order to explain the greater strength of an iron treated by Mr. Johnson's process.

The internal chill described by Mr. Johnson has been produced by Keep and others by simply immersing a cylindrical test-piece in water after the outside has cooled and while the interior is still liquid. This experiment can be repeated by any one, and it demonstrates that the iron can be chilled only while still liquid. A photograph of a chill so produced is shown in Fig. 1.

I will pass over a discussion of the effect of the various metalloids on the physical properties of cast iron, but in 1896 I made

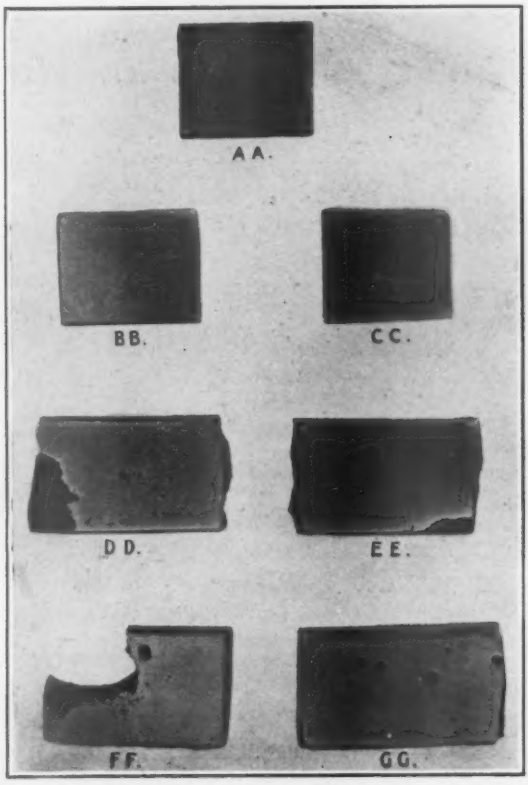
FIG. 3.



a very extensive investigation into the effect of carbon, phosphorus, sulphur, silicon, and manganese on cast iron. They confirm, in a general way, the views set forth by Mr. Johnson, and especially do they confirm the statement that combined carbon has the most profound effect on cast iron. As a result of these experiments we discontinued entirely the analysis for graphite, and confined our efforts to determinations of combined carbon, and these views are now generally accepted and very few manufacturers make determinations for graphite except for experimental work.

I take this occasion to call attention to a valuable article on liquid contraction of cast iron by Hailstone,[1] published as the Carnegie Memoir by the Iron and Steel Institute. The object of the investigation was to discover why iron castings which appear solid on machining develop leakage under hydrostatic test, and

FIG. 4.



the inability to trace the defect by means of chemical analysis. A special type of test-bar was employed, which resembled in general the letter "K," a photograph of which I am showing (Fig. 2). These bars were poured at intervals from a ladle, so that the various test-bars were poured at different temperatures. It was found that the iron underwent a profound change, and that

[1] Carnegie Scholarship Memoirs, vol. 5, 1913, p. 51.

after passing a critical point it seemed to be very definite and pronounced. The experiments further show that with low pouring temperatures there is a corresponding decrease in hardness, density, and strength, and that blowholes appeared only in castings poured at a low temperature. I am showing fractures of these test-bars poured at various temperatures.

FIG. 5.

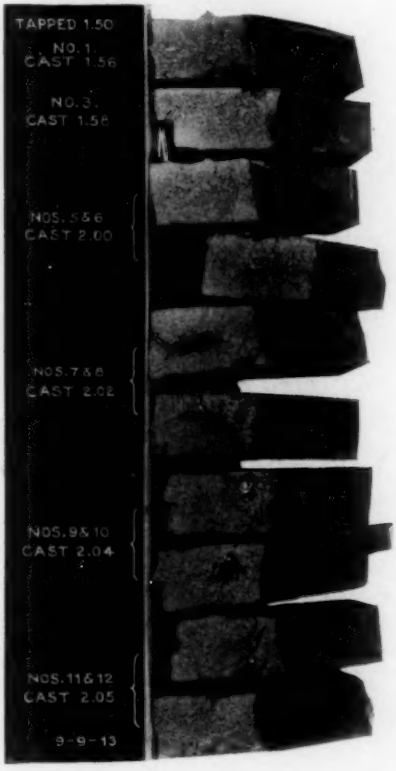
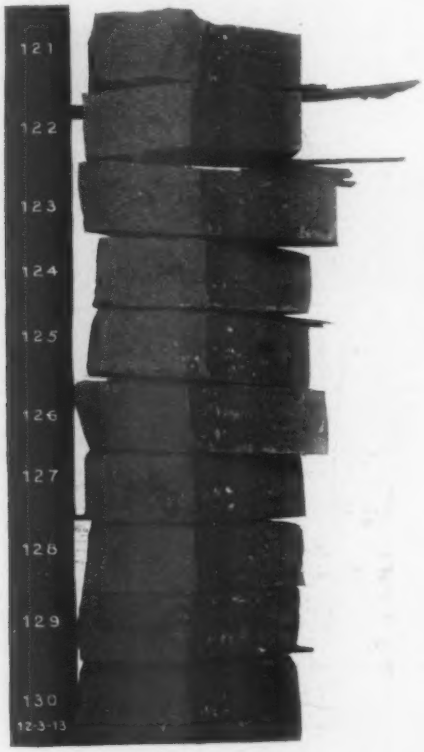


Fig. 3 shows the results of Hailstone's experiments. Test-bar *AA* was first cast, the other bars being cast at successive intervals of from one to two minutes, test-bar *GG* being cast 6½ minutes after test-bar *AA*. It will be noted that *AA*, *BB*, and *CC* are free from blowholes or liquid contraction, whereas *DD*, *EE*, *FF*, and *GG* contain gasholes and blowholes. Hailstone's analysis gives

the gas evolved in heating these specimens for 12 hours at 950° C., and in no instance did he report the presence of any oxygen whatever, the constituent gases being CO and H_2N_2. He further reports a gradual decrease in the volume of the gas generated with a decrease in the pouring temperature.

Test-bar *AA* contains .392 cubic centimetre per gramme, while sample *GG* contains .096 cubic centimetre per gramme. He

FIG. 6.



further reports an increase in the size of the graphite crystals in the constant decrease in the strength of the iron in the samples that were poured cold at a low temperature. These elaborate and scientifically conducted experiments would seem to have a direct bearing upon Johnson's experiments. The casting temperature is undoubtedly increased by Johnson's method, which, in the light of Hailstone's experiments, would seem to have a more

direct bearing on the quality of the product produced than the possible presence of oxygen. Furthermore, Hailstone shows by actual measurements that the graphite crystals are smaller in the hot-cast test-piece than in the cold-cast test-pieces, so that the difference in microstructure reported by Johnson can also be explained by a mere difference in casting temperature. This ex-

FIG. 7.

planation of the results obtained by Mr. Johnson seems much more rational than that proposed by him.

Fig. 4 shows a sectional view of Hailstone's test-bars.

Fig. 5, 6, and 7 show a practical application of Hailstone's experiments in an iron foundry. The time the iron was tapped and the time of pouring the test-pieces are shown in the various figures.

Fig. 5 shows an ordinary heat of iron, the first bars cast being free from defects, whereas those cast after the iron had an opportunity to cool show the effects of liquid contraction.

Fig. 6 shows a cold heat of iron, and practically all the test-pieces contain defects, whereas Fig. 7 shows a hot melt of iron, in which all of the test-pieces are free from defects. These results would indicate that many of the internal defects in cast iron could be eliminated by superheating the iron in a fore-hearth after it is tapped from a cupola. This superheating could best be done by an electrical furnace, and the small amount of heat which it is necessary to impart should not greatly increase the melting cost of the iron.

CLOSURE BY THE AUTHOR.

In spite of my regard for the investigations and achievements of Professor Outerbridge, I am compelled to differ with his understanding of my explanation of the action which takes place by the introduction of oxygen into iron. The process is in no degree a refining process, because, while silicon is taken out, it is restored by the addition of the untreated metal, and the carbon is scarcely affected at all. The fact that the process is a pneumatic one has no bearing whatever on the subject. We could as well introduce the necessary oxygen by the use of an oxidizing slag or perhaps by one or two other methods, but these would not be quite so convenient, and would not be under the strict control of the Bessemer, and therefore would not be as good practically.

I have tried to make clear the difference between my iron and semi-steel, so called, and to point out that, while that material may be made strong, this is done at the sacrifice of the carbon, which is bad both for chilling purposes and for machining.

In regard to Mr. Wille's discussion, while I am in agreement with the major portion of it, I am compelled to differ with his statement of the reason for the superiority of charcoal over coke iron. It is true that charcoal is more soluble in iron than coke, or at least that charcoal irons are apt to be higher in carbon than coke irons, but I have tried to make it very clear that this high total carbon falls out of combination and turns to the graphitic form more than lower total carbons. It is true that good charcoal irons retain a larger portion of their carbon in the combined condition, but this is entirely due to the presence of oxygen in them.

since we have repeatedly proved that irons high in carbon, without oxygen to prevent its precipitating out, are poor almost to the point of being worthless.

I must explain that Mr. Wille has received a wrong impression in regard to one matter. We are particular *not* to remove very much of the carbon, and owing to the laws of chemistry we are very successful in retaining it in the iron, because at the low temperatures which we use the silicon almost all disappears before the carbon begins to burn, and we have, therefore, only to stop the blow to retain almost all the carbon. We have recently made irons containing as high as 3.8 per cent. of this element, and hope to do better than this when we have obtained better facilities.

Mr. Wille finds it impossible to believe that oxygen can remain in molten iron in the presence of such strong dioxidizers as silicon, manganese, and carbon. This point of view is not surprising, and was at one time very strongly held by no less an authority than Professor H. M. Howe, but on more careful examination this fact is seen to be in line with a vast array of other facts dealing with dilute solutions, since it has been abundantly proved that reactions which go to completion in concentrated solution do not go to anything like completion in dilute solutions as an equilibrium point is reached before the reaction is concluded. This is the case in regard to oxygen and also in regard to sulphur to about the same extent. It is well known that sulphur is slagged out by manganese, and that the weight of manganese required is only about twice that of the sulphur when the two are chemically combined, which would mean that for ordinary iron less than 0.2 per cent. manganese would be required for the complete elimination of the sulphur. But we know, as a matter of fact, that this is not true; that it does not begin to be true. Two or three times this amount of manganese is required to make a substantial reduction in the sulphur, and this reduction soon reaches a practical maximum which no further addition of manganese will increase. So it is with oxygen: at a certain temperature 3.8 per cent. carbon and, say, 1.25 per cent. silicon will eliminate all the oxygen down to about 0.06 or 0.07 per cent.; if the temperature be raised or if manganese be added, this quantity will drop until there may be as little as 0.01 per cent. oxygen remaining, or even less. But as to the actual presence of oxygen in iron there is no room whatever for doubt. After many months of careful research work carried

on by one of the best chemists I have ever known, we were able to reach conclusions which have since been abundantly checked by analyses made for me by the American Rolling Mill Company, which has a very large research laboratory, and which has specialized in oxygen determinations.

In regard to the internal chill of spotted iron there is also, I think, a misapprehension. I have seen such an internal chill produced, and it is in the way that Mr. Wille describes, by quenching a casting whose interior is still molten after its exterior has been allowed to harden in the air. But a spotted iron does not require this or any other treatment to show its characteristic "spot," which, by the way, is entirely different from the appearance of the internal chill produced as described. Not only is no treatment necessary, but no treatment of which we have knowledge is sufficient to prevent the formation of the spot, unless it may be extremely slow cooling. This spot is due to the concentration of the carbon at the centre of the pig, forming a eutectic or easy-melting substance at that point which stays liquid until the iron around it has become so rigid and has contracted upon it so tightly that the expansion which would occur on the formation of graphite cannot take place, and the carbon is therefore held in the combined condition.

The effects of pouring temperatures are undoubtedly very important; but it will be observed that in our experiments we completely eliminated the possibility of the results we obtained being due to a variation in pouring temperature by making remelts of the strong irons and weak ones in crucibles which prevented any substantial alteration in their composition, and we found that their characteristics were preserved absolutely on remelting. It is therefore absolutely impossible to attribute the results which we have achieved to any change in the melting temperature, and incidentally I would like to say that we do not raise the melting temperature of the iron, as stated by Mr. Wille. On the contrary, we take the pains to blow the iron cold and to keep the temperature just as low as we can without danger of skulling, throughout the operation; we cannot get the best results by any other method. But after the iron is once made it can be remelted as hot as desired, within reason, without injury.

In conclusion I would like to say that I think the doubt remaining in the minds of Messrs. Outerbridge and Wille as to the

possibility that oxygen is accountable for the results described is due to the fact that it was impossible in a lecture to take the time to make a complete presentation of this subject. If they would study the data given by me, and those given in my paper, "The Effect of Oxygen, Nitrogen, and Some Other Elements on the Quality of Cast Iron," before the American Institute of Mining Engineers, and also the very remarkable results which we have been able to obtain by no other changes in the composition save the content of oxygen, I am sure they would be convinced that this element, and this alone, is accountable for the results which we have obtained. The many facts of practice, such as the use of the air furnace with the oxidizing flame for the production of strong castings, and the irons of remarkable strength produced from the blast furnace when oxidizing conditions and low temperature prevail in its hearth, furnish ample confirmation of the oxygen theory, but an insuperable obstacle to any other now existing, and I have little doubt that Mr. Wille and Professor Outerbridge will ultimately accept the former as our knowledge of this subject grows.

Paraffin Wax Industry of Austria. P. PORGES. (*Z. Angew. Chem.*, xxvii, iii, 41.)—To enable Austrian lubricating oils to compete with Russian and American oil the paraffin wax is separated as completely as possible. About 95 per cent. of the Austrian works use the patented apparatus of Porges, Singer, and Steinschneider, and produce 6500 wagon-loads of purified wax per annum. The oils are gradually chilled by passing them through a series of connected crystallizing chambers surrounded by coils through which brine is pumped. The semi-solid mass from the chambers is pressed, usually in filter presses, and the filtrate again partially chilled before being suitable for lubricants. The residue in the press, termed "gatsch," is usually submitted to dry sweating to expel the oil. A recent improvement is the introduction of Pejzel's apparatus, in which the sweating vessels are mounted on trolleys which pass through a ventilated passage. After leaving the sweating vessels the wax is decolorized with sulphuric acid and "silicate." The system of moist sweating, which is little used, aims at utilizing the hot liquor from the crystallizing chambers. Fractional crystallization of the wax is effected by chilling the chambers in stages. One part of the apparatus works at 0° C., a second at −5° to −7° C., and a third at −10° to −18° C.; and in a patent process of Pejzel and Porges each chamber is chilled so as to yield a paraffin wax of a definite melting-point.

Repainting Tests on Paint Oils. HENRY A. GARDNER. (*Circular No. 30,* Paint Manufacturers' Association of the United States.)—In May, 1911, there was exposed at Washington a series of wooden panels painted white. The pigment mixture used in the paints was the same for each test, but the liquid portion of each paint was varied. The tests were made in order to determine the relative durability of various oils as paint vehicles. Complete information was given in a paper entitled "The Practical Testing of Drying and Semi-Drying Paint Oils," as presented before the American Society for Testing Materials (*Proc. A. S. T. M.,* 1911, p. 641). The tests have now been repainted. At definite periods, previous to repainting, photographic records of the appearance of each paint were made. This accumulated data will be available when the repainting tests have sufficiently weathered. Previous to repainting, the surface of each panel was lightly sanded to remove any surface defects. The paint was then applied directly to the panels upon the exposure rack. Five per cent. of drier was added to each paint. For the first coat, reduction with a pint of turpentine to a gallon of paint was made. The second or finishing coat was applied without reduction. A period of one month was allowed for drying between coats. As none of the paints used for the original painting of the panels had been reserved, it was necessary to make up another quantity of each for the repainting tests. For this purpose a quantity of the original white pigment mixture, ground to a stiff paste in fourteen parts of raw linseed oil, was prepared. Many of the oils used in preparing the different paints for repainting were portions of the quantities originally used in the first set of paints. Analysis of these oils shows that some action has occurred in them during the last forty-two months, their constants in some cases varying from the constants shown when the oils were first analyzed. In a previous investigation the writer has pointed out the effect of enzymes upon oils and oil-paste paints, and has shown that such effects may be inhibited by sterilization. A series of experiments designed to throw more light upon this question is now under way.

Nickel-plating Aluminum. ANON. (*Metal Ind.,* xii, No. 9, 378.)—M. Le Chatelier has just presented a communication to the Académie des Sciences, stating he has succeeded in nickel-plating aluminum, which has not been accomplished by the ordinary methods. This has prevented the extensive employment of the metal on account of its dull appearance. This difficulty has been surmounted by a preliminary scouring of the aluminum in a bath of hydrochloric acid containing a certain proportion of iron. The iron precipitated on the surface of the aluminum forms a kind of network, and when the metal is passed into a nickel bath the nickel gets entangled in this network and adheres strongly to the aluminum. This process, which is based on a physical action, appears to solve the problem which had been considered insoluble hitherto.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PRINTING INKS.†

THE purpose of this circular is to give a general description of the composition, manufacture, and properties of some of the common types of printing inks.

The materials entering into the composition of printing inks are divided roughly into two classes, viz., oils and pigments. The first class includes linseed oil, rosin oil, the various semi-drying oils, gums (resins), rosin, and soap. The second class includes the various pigments from which the inks derive their color, and, to some extent, their consistency and working qualities. A brief description of the preparation and properties of these materials is given. The subject of driers is treated in a separate chapter. Various formulas are given showing the approximate composition of some inks.

The manufacture of printing inks is described, showing the method of preparing the oil varnish and pigments, the methods of mixing and grinding, etc.

The circular then takes up the question of the relation of ink to the paper. To obtain satisfactory results in printing, these two factors, ink and paper, must be carefully adjusted. It is well known that an ink which is satisfactory on one paper will not be so on another, all other conditions being constant. One phase of this relationship between ink and paper is the opacity of the ink, a subject of particular importance in the three-and-four-color processes. Emphasis is laid on the necessity for the printer to select the proper grades of paper which will be suitable for his work.

The question as to what constitutes a good ink is often asked, and, while this circular does not pretend to answer this directly, it gives the requirements and tests specified by the Government

* Communicated by the Bureau.

† Circular No. 53.

Printing Office, which show how one government department is handling this problem.

The Bureau of Standards has issued a technologic paper on the subject of the analysis of printing inks, an abstract of which is included in the circular. The application of these tests and their relation to the practical tests under working conditions are given.

Owing to the importance of linseed oil in printing inks, a special chapter is devoted to the manufacture and properties of this oil.

A bibliography on inks, oils, and pigments is included for the benefit of those who wish to make a deeper study of the subject than the general nature of the circular permits.

REGULATION OF ELECTROTYPING SOLUTIONS.*

THIS circular has been prepared to meet the demands of electrotypers for such information as is available on the operations involved in copper and nickel electrotyping. Owing to the small amount of scientific information available upon this subject, this edition of the circular is confined to a general discussion of the possible results of such work, and to simple methods for testing and adjusting the acid copper sulphate electrotyping baths. A preliminary study of the problems of electrotyping is now being conducted by the Bureau of Standards in coöperation with a special committee of the International Association of Electrotypers. From the results of this preliminary work it is hoped to outline and conduct a more exhaustive investigation of these problems.

EXCERPTS FROM THE REPORT OF THE DIRECTOR OF THE BUREAU FOR THE FISCAL YEAR ENDING JUNE 30, 1914.

SINCE the Bureau of Standards deals almost entirely with scientific and technical problems, the following brief statement as to its functions and organization may be of assistance to those who are more or less unfamiliar with its work.

The standards with which the Bureau is authorized to deal may be conveniently classed as follows: First, standards of meas-

* Abstract, Circular 52, issued January 25, 1915.

urement; second, standard values of constants; third, standards of quality; and, fourth, standards of mechanical performance.

I. STANDARDS OF MEASUREMENT.

A standard of length may be taken as an example of a standard of measurement. It must be a length which is unchanging, reproducible, and capable of being compared with the working standards used in the most precise scientific work or with those used in commerce and industry. The fundamental standard must be subdivided and working standards prepared of these parts; for the measurement of greater lengths, standards must be prepared which are multiples of the fundamental standard. This process of subdividing and multiplying the standard involves even more difficulties than those met with in the preparation of the fundamental standard itself.

The construction of a set of standard weights from a single unit is also an illustration, but a whole set of standard weights must be prepared before the standard weight of the Government can become available to the public. When the standard of length or weight has been found with as many desirable qualities as possible, and before the working standards of the subdivisions or multiples can be prepared, the question as to the method of comparison arises which again involves the solution of difficult scientific problems in connection with the balance or the methods used. These balances range from that capable of measuring the thousandth part of a milligramme to the large testing machine capable of measuring a load of thousands of tons. The complete range must be covered, which involves not only a large number of working standards, all of which must agree with the fundamental standard, but apparatus suitable for the comparison of these standards with all of the lengths or weights found in practice.

These steps and equipment are absolutely essential in order to secure uniform measurements of length or weight throughout the country, and they have their counterpart in every quantity that has to be measured, whether it be length, weight, temperature, heat, light, or the various electrical measurements or other standards of measurement. These standards in one form or another are involved in practically every scientific investigation, industrial process, or engineering structure.

2. PHYSICAL CONSTANTS.

There are many fixed relations between physical quantities, the values of which it is extremely important to know. These values are usually termed "physical constants," and are used in every branch of scientific work or industry. The amount of heat required to change a pound of water into steam under normal conditions and the relation between heat and mechanical energy are two important physical constants; their values are used in practically every computation in connection with the designing of steam engines and boilers, the tests of their efficiencies or the measurement of their output. The amount of heat required to turn liquid ammonia into vapor or the amount of heat required to melt a pound of ice are constants equally important in the refrigerating industries. The value of the relation between electrical and mechanical energy is involved in many important commercial transactions concerned in electricity.

Accurate and authoritative values of these constants are just as essential as in the case of standards of measurement. Many of these now in use are old and obsolete and need redetermination by means of the best modern facilities for physical measurement. Their determination involves the most difficult and precise work in all branches of physics and chemistry—a fact not generally known by others than those engaged in the scientific and technical work where these constants are used.

3. STANDARDS OF QUALITY.

A standard of quality for a given material may sometimes take the form of a sample of that material with which other materials of the same kind can be compared, but this is generally a makeshift of the poorest sort. It is only resorted to in the absence of definite and reliable specifications in terms of measurable properties; that is to say, a standard of quality of a material usually takes the form of a specification or definition of its properties, involving, of course, the measurement of those properties by means of the usual standards of measurement. A certain kind of steel, a cement, a paint, an oil, or a paper or cloth is found by use to be good or poor. The question then arises, Why is it good or poor; what are the physical or chemical properties or the particular combination of elements which make it of good or poor

quality; how are its properties to be measured or its constituents determined? These are questions for the laboratory to answer, and involve physical and chemical investigations of the most difficult sort.

A standard of quality for a given material necessarily takes into account the purpose for which the material is to be used; to set the standard too low results in losses, poor efficiency, and even loss of life; to make it too high may result precisely in the same thing; that is to say, the material must be suitable for the purpose intended, and the Bureau's investigations in connection with the properties of materials are to enable the user of these materials, first, to select intelligently the material best suited for the purpose; second, to specify it in terms which the producer cannot mistake; and, third, to make the necessary tests to ascertain whether or not the material supplied is in accordance with the specifications.

The actual testing of materials by the Bureau of Standards to ascertain whether or not they comply with specifications is confined almost exclusively to Government purchases, but in making these tests (in which the Bureau has had the hearty coöperation of practically all the departments of the Government service) it is compelled to make many investigations concerning the properties of materials, their specification and measurement. While this work is of great value in placing Government purchases on a correct business basis, the results of the investigations as to the properties of materials and the information gained in testing Government supplies are even more important to the general public, and are distributed in the form of suitable publications.

The Bureau does not compete with private testing laboratories, but endeavors to assist them by the development of standard specifications, methods of measurement, and other matters where uniformity is desirable, much of which information, as stated above, is secured in connection with the testing of materials purchased by the Government and a close observation of their use.

The time is not far distant when it will be required that all materials bought or sold shall be as represented, but it should be kept in mind that this is impossible except in the case of those materials where proper standards of quality and methods of measurement have been developed. It must not be assumed that the purchaser or user is the party principally benefited in the

development of such standards; on the contrary, the manufacturer, first of all, is interested in the quality and all things which affect the quality of his product, and, while the Bureau's efforts in this field are devoted principally to the pointing out and measurement of those properties upon which the quality of the materials depends, it is to be regretted that its force and equipment are insufficient to render more assistance to manufacturers with a view to a direct improvement of those parts of the process upon which the quality of the output depends.

4. STANDARDS OF PERFORMANCE.

The value of an instrument, device, or machine almost always depends upon the efficiency of its performance. In such cases it is necessary to state the performance desired or guaranteed in terms which are correct and susceptible of measurement. As in the case of standards of quality, the standard involved is more often in the form of a specification, but specifications are useless unless based upon correct scientific and mechanical principles and supplemented with a statement of the method to be used in ascertaining whether or not the specifications or guarantees have been complied with.

The performance of an engine or boiler, a pump, an electrical generator or motor, a weighing device, or a telescope can usually be measured, but the quantities to be measured and the method used must be specified correctly and understood by all the parties concerned in the construction, purchase, or use of such apparatus. To do this properly involves the use of standards of measurement, standard values of constants, and standards of quality. The Bureau of Standards does not attempt to cover this field completely, but only those cases where there is a lack of definite information upon which to base specifications, and only to the more important classes of apparatus. To secure this information involves investigations quite as scientific in character and as difficult as in the case of other standards, as well as a knowledge of technical and manufacturing processes.

The Bureau's activities in this field have only been developed to a slight extent and almost entirely in connection with Government purchases. It has had in this, as well as in the field of the properties of materials, the most hearty coöperation of the various

Government experts, manufacturers, engineers, and technical societies.

Government purchases are not greatly different from those of the public. Whenever the Bureau makes a scientific investigation or secures information from other sources for the purpose of the improvement of specifications used in connection with Government purchases, whether for measuring instruments or for materials or equipment, such information or data are given to the public in the form of suitable publications. The value of this information from the stand-point of the public is even greater than that in connection with Government purchases, important as the latter is. In other words, the needs of the public and the Government service are precisely the same so far as standards or specifications are concerned, whether it be standards of measurement, quality, or performance.

In the case of the public, the Bureau confines its work to those investigations, experimental or otherwise, which enable it to give intelligent advice regarding the use, purchase, and testing of the more important apparatus and materials, leaving the testing to commercial laboratories; except, of course, in the case of standards of measurement, where it is absolutely essential that the standards of the public be compared with those of the Government to secure uniformity of measurement, and in unusual cases of testing where the public is not yet provided with suitable means or equipment. In the case of the Government, the Bureau goes further and serves as a testing Bureau for the various departments when called upon, and as such is assisting to place Government purchases upon an economical and business-like basis. The example of the Government in such matters has a far greater influence upon the public than most people suppose. The Government can do no greater service to the country than to place its own purchases on a basis which may be taken as a standard by the public at large.

5. RELATION OF THE BUREAU'S WORK TO THE PUBLIC.

It is perfectly obvious, even to one unfamiliar with the subject, that the maintenance on the part of the Government of correct standards of measurement or quality or performance calls for continuous scientific and technical investigations of the highest grade, involving the most competent expert services and the best

scientific equipment. When this is accomplished, there still remains the serious problem of making the results available and useful to the public.

The Bureau compares with its own standards of measurement the standards or measuring instruments of States, cities, scientific laboratories, educational institutions, manufacturers, Government bureaus, or the public, for which a nominal fee is charged, except in the case of the National and State Government institutions. It gives advice concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of everyday trade or in connection with precision standards used in scientific work and the industries. It gives advice upon request to State and city officials, public-service commissions, public-utility corporations, regarding the standards of measurement, of quality or performance, involved in legislation or regulation pertaining to the public utilities. Many questions of disagreement between the public and utility companies as to these matters are referred to the Bureau for advice or adjustment, often avoiding unfair or inconsistent regulations, as well as long-drawn-out and expensive litigation. There is a great need on the part of the public for unbiased and reliable information pertaining to the standards entering into the regulation and sale of the services of public utilities. So far as possible such information is given in the form of publications upon definite subjects.

It must not be inferred from the above that the Bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the Bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Agricultural Department do to the agricultural interests. Many industries are just beginning to realize the importance of precise methods of measurement and scientific investigation, which, in practically every case, involve some kind of measurement.

It is upon quality as well as upon price that competition must finally depend, whether in domestic or foreign commerce. The

use of exact methods and scientific results is the greatest factor in the improvement of quality, efficiency, or the development of new industries. The educational value of the Bureau's work in this respect is almost entirely unknown to the general public, and yet the Bureau receives hundreds of letters, as well as many personal visits from manufacturers, seeking information as to standards of measurement, how to use them, how to measure the properties of materials, or as to the fundamental physical and chemical principles involved; also, what is of even greater importance, how to initiate and carry out scientific investigations and tests on their own account in their particular fields of work.

The importance of maintaining scientific institutions having to do with standardization and the application of precise measurements to the industries has been recognized by all the leading countries of the world. Great Britain maintains the Standards Department of the Board of Trade, which is in charge of the standards and inspection service of the trade weights and measures; also the National Physical Laboratory, whose functions include matters pertaining to scientific and technical standards, physical constants, and to some extent the properties of materials. The Laboratoire d'Essais, of France, while not as extensive as the English institution, is charged with similar duties. Germany maintains three such institutions—the Normal-Eichungs Kommission, equipped with the buildings, personnel, and apparatus necessary in standardizing and controlling the weights and measures of trade; the Physikalisch-Technische Reichsanstalt, covering testing and investigations in connection with scientific and technical standards other than weights and measures; and the Prussian Government maintains the Material-prüfungsamt, a large institution devoted to the investigating and testing of structural, engineering, and other materials.

It is generally recognized that these institutions have been exceedingly important factors in the industrial progress of these countries.

Electric Field of the Sun. H. Deslandres. (*Comptes Rendus*, clviii, 1137.)—This is a discussion as to the possibility of certain phenomena exhibited by the solar atmosphere being wholly or partly due to the Stark effect. Attention is drawn to the differences shown by laboratory experiments between the Stark electrical effect and the Zeeman magnetic effect.

Petroleum Exhibit, Panama Pacific International Exposition.—The United States Bureau of Mines is preparing an exhibit of petroleum and the petroleum industry for the exhibition to be held in San Francisco, beginning February 20. The principal part will be located in the open, the space belonging to the Department of Mines and Metallurgy, and will cover about 52,700 square feet of ground.

An auxiliary exhibit will be installed in the Palace of Mines and Metallurgy, which will include a large collection of mine products from many oil fields of the United States and abroad.

A second auxiliary exhibit will be installed in the Palace of Machinery, where a large number of typical fuels, lubricants, and materials used in modern machinery practice will be shown.

The petroleum exhibit will consist of nine principal divisions, as follows: (1) A pictorial display, (2) a geological display, (3) a statistical exhibit, (4) a library of petroleum literature, (5) a technological exhibit, (6) the display of a large collection of crude and refined products, (7) an exhibit displaying housing and sanitary problems, (8) lectures, (9) an exhibit displaying fire hazards and methods of preventing and fighting fires.

The World's Petroleum Congress is scheduled to meet October 25–30 in the exhibition city, and will be attended by all persons interested in the petroleum industry. A number of technical and scientific papers from Americans and foreigners is assured, and the programme will be divided into several divisions. Special excursions to the great petroleum fields of California and Oklahoma are being arranged.

Coal for Coke. ANON. (*Metal Ind.*, xii, No. 10, 429.)—In the last five years the coal used in metallurgical coke manufacture has averaged around 65,577,000 tons, yielding 43,983,000 tons of coke, valued at $111,736,000. Of this total, 14,767.000 tons were used in by-product coke ovens, yielding, besides the coke, 54,491,000 cubic feet of gas, 94,306,000 gallons of tar, and $9,109,000 worth of ammonia. When it is considered that every year approximately four times these enormous totals of by-products are absolutely wasted through the use of non-by-product ovens, the vital importance to the country of a general use of the modern, scientific by-product ovens will be appreciated.

Purifying Copper. (Brit. Patent 6286, of 1913; *Elect. Engineering*, x, 216.)—According to the General Electric Company (U. S. A.), copper of a high degree of purity is obtained by melting the copper above a mixture of inert material and boric anhydride. The temperature is kept at about 1300° C., while the boric anhydride is kept beneath by the inert material and the mass is stirred until the boric anhydride rises to the surface. The process may also be applied to silver, gold, etc.

THE FRANKLIN INSTITUTE

ANNUAL MEETING.

(Abstract of Proceedings.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 20, 1915.

DR. JAMES MAPES DODGE *in the Chair.*

Additions to membership since last report, 9.

Mr. George R. Henderson presented the report of the Committee on Science and the Arts.

The tellers of election, Messrs. Jennings, Cullen, and Colvin, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

James M. Dodge, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Charles Day, Alfred W. Gibbs, J. J. Gibson, George R. Henderson, George A. Hoadley, Isaac Norris, Jr., Lawrence T. Paul, James S. Rogers, Managers (to serve three years).

The Chairman presented the President's statement of the work of the Institute for the fiscal year ending September 30, 1914. (Appended.)

Following the business meeting of the Institute, a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, and Mr. H. F. Sanville took the chair with Dr. Dodge.

Mr. William S. Murray, Consulting Engineer, New York, New Haven, and Hartford Railroad, Hartford, Conn., was introduced and presented an interesting communication, entitled "Conditions Affecting the Success of Main Line Electrification," in which he gave a general exposition of his experiences in connection with the construction and operation of the electrified portion of the New York, New Haven, and Hartford Railroad. He drew from this the significant factors determining the success of heavy trunk line electrification, and pointed out how these factors could be generally applied.

The paper was discussed by several members present, after which a rising vote of thanks was accorded the speaker.

Adjourned.

R. B. OWENS,
Secretary.

PRESIDENT'S REPORT AND REPORTS OF THE COMMITTEES OF THE INSTITUTE AND THE COMMITTEES OF ITS BOARD OF MANAGERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Members of The Franklin Institute:

Your Board of Managers, in addition to inviting a close study of the reports of the several committees covering the activities of the Institute during the year ending September 30, 1914, and presented herewith, earnestly call your attention to several matters of the first importance to the Institute, and to that progress in mechanic arts which it is the Institute's function to promote.

Previous reports of the Board have kept you concurrently familiar with the continuing satisfactory progress of the general work of the Institute. Our membership has recently been greatly enlarged; the attendance at our lectures frequently taxes the seating capacity of our Hall; through the JOURNAL OF THE INSTITUTE our membership and the scientific world generally are promptly and authoritatively informed of the results of the latest researches in physical science and the most recent achievements of the engineering professions; the year's additions to the Library are more than usual; the work of our Science and Arts Committee has, as always, been marked by devotion and efficiency; the usefulness of our School of Mechanic Arts, notable for nearly ninety years, has never been greater than at present. These facts, while offering gratifying proof of the continuing usefulness of our Institute, should not satisfy us, in view of the opportunities for greater service which, as we believe, the near future offers.

As you are aware, the Institute owns a site upon the Parkway, perfectly located, and entirely sufficient for such new building or buildings as will best serve to enable it to meet these opportunities. Four years ago the Institute's income would not have been sufficient to maintain a modern adequate structure and to carry on therein, in the fullest degree, the work formulated in its charter. After this year, however, in the event of the friends of the Institute meeting the conditions of the Wahl bequest, the Institute will possess such an annual income as would justify it in so occupying a modern building as to greatly increase the extent and value of its services in the special field of its efforts. This building, on the south side of Logan Square, at the corner of Nineteenth and Race Streets, when erected, will have for its neighbors, as you know, the Cathedral, the Wills Hospital, the Academy of Natural Sciences, and the great and noble new Public Library. The building thus worthily located will face Logan Square and have a frontage of 110 feet and a depth of 130 feet. The entrance will be on Race Street, and the façade, while simple, will be dignified and in keeping with the purposes of the structure and with its location. The ground floor will be devoted mainly to laboratories, notably a thoroughly-equipped testing laboratory for the use of the Committee on Science and the Arts. On the first floor will be located the main Lecture Hall, fitted with every modern appliance for lecture demonstration and experiment, with a large members'

room, apparatus and model rooms, offices and preparation rooms. The second floor will contain well-equipped lecture rooms for the use of such scientific and technical societies as may wish to use them, together with a number of office rooms and a Board room. The third floor will be occupied by the School, and the fourth floor will be devoted entirely to the Library.

We have only about one-third of the money necessary for such a building as we desire to erect; we own, however, what we believe to be the building site best located for the purposes of the Institute, and we believe that our annual income within a year or two will warrant the Institute in occupying such a building should the funds necessary for its erection be obtained. We therefore particularly urge, first, that the members and friends of the Institute see to it that the conditions of the Wahl bequest be promptly met; and, second, that the necessary money for the completion of the building fund, approximately half a million dollars, be obtained through private contribution or public grant: all this, that the work of the Institute may result in increased benefit to the citizen and to the State.

Recalling that the Institute's success in its efforts to promote the mechanic arts depends upon the degree of intelligence and devotion exercised in the committee rooms and in the office of the Secretary, your attention is again invited to the Board's and Institute's Committee reports and to our latest Year Book, as evidence adequate, though not comprehensive, of the ability of our Institute to-day to call to its service devotion and intelligence of the highest order.

Respectfully submitted,

FOR THE BOARD OF MANAGERS,

WALTON CLARK,
President.

PHILADELPHIA, January 20, 1915.

REPORT OF THE COMMITTEE ON LIBRARY

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

During the year there were expended $910.26 for the purchase of 306 volumes, 1 pamphlet, and 3 maps; $1575.92 for subscriptions to periodicals; $750.35 for binding 328 volumes; $4267.86 for salaries and expenses. There were available for meeting these expenditures $6650, appropriated by the Board of Managers, and $1271.10, being the income from the several Library funds.

The accessions by gift, exchange, and from the JOURNAL totalled 1192 volumes, 955 pamphlets, 3 maps, and 1 drawing.

The additions include many valuable works. More books have been purchased than in the previous year, and the falling off in the total additions is due only to a decrease in the accessions of pamphlets. Much valuable

and interesting material has been secured by continuing the practice of applying to engineering firms and industrial establishments for their publications.

Three hundred and eleven pamphlets on mechanical subjects, most of them accessions of the current year, were classified, indexed separately, and bound into thirty-three volumes, and now form a part of the mechanical section. The work of classifying the pamphlets still stored was begun, but the progress is somewhat slow. The electrical and chemical pamphlets are being sorted out for indexing and binding.

Library Bulletin No. 3, being the second list of additions to the Library, was compiled and issued in September, and was also published in the JOURNAL.

On September 30, 1914, the Library contained 65,437 volumes, 48,955 pamphlets, 2279 maps and charts, and 1336 photographs.

The work of recording the status of the current periodical sets has been continued throughout the year and is progressing favorably. As this work proceeds, efforts are made to obtain missing volumes or parts of sets. The purchase of a dozen volumes completed the file of an important chemical journal published in Germany.

The subscription list was revised, but it was found that only three publications could well be discontinued.

In the binding of books and current periodicals as satisfactory progress has been made as possible, but, as pointed out in previous reports of this Committee, the requirement of a special fund to permit of a greater expansion of this work still exists.

The Committee held ten stated meetings during the year, at which many valuable suggestions were made and considered. At a recent meeting attention was called to the desirability of systematically going over each of the various subjects and departments with the view of ascertaining which of these were lacking in completeness, and on which the money available could be most profitably expended by the acquisition of recent works. It is only by the adoption of such a plan that the branches of the Library can each be maintained at its proper standard.

By removing about 4500 volumes to the overflow stack in the basement, space for recent acquisitions was secured.

There was a very gratifying increase in the attendance, especially on the evenings on which the Library was open until 10.00 P.M.

Appended hereto is a detailed statement of the operation of the Library during the year.

Respectfully submitted,

CLARENCE A. HALL,
Chairman.

PHILADELPHIA, January 13, 1915.

APPENDIX.

The following additions were made to the Library during the twelve months ending September 30, 1914:

SOURCE	Bd. Vols.	Unbd. Vols.	Pphs.	Maps	Drawing
Gift	591	535	913	3	
Exchange account	1				
JOURNAL	16	49	42		1
Binding new volumes:					
Institute appropriation	328				
Chemical Periodical Binding Fund	26				
Moore Fund	1				
Morris Fund	33				
Purchase:					
Institute appropriation	16	4		1	
Lea Fund	55	12	1		
Memorial Library Fund	1	2			
Moore Fund	166	16		2	
Morris Fund	33				
Potts Fund	1				
	1268	618	956	6	1

Total additions for the year 2849

Gifts of books, pamphlets, and periodicals in large quantities or of special value were received as follows:

Mr. H. M. B. Bary, copies of recent trade publications.

Booth, Garrett & Blair, volumes and pamphlets on mining and metallurgy.

Crocker-Wheeler Company, Philadelphia, Pa., electrical publications.

Electric Storage Battery Company, engineering and trade publications.

Mr. Guy H. Elmore, pamphlets and copies of society publications.

The Engineers' Club, engineering publications and Society Transactions of 1913.

Mr. Spencer Fullerton, several lots of pamphlets and magazines on various subjects.

Mr. F. Lynwood Garrison, magazines on mining and metallurgy.

The General Electric Company, copies of its publications.

Mr. J. J. Gibson, historic electrical pamphlets.

Mr. Clarence A. Hall, books, pamphlets, and maps on chemistry and metallurgy.

Dr. Carl Hering, books, pamphlets, and magazines on electrical and other subjects.

Miss Houston, electrical magazines.

Mr. Louis E. Levy, publications on photography and printing.

Mr. R. Louis Lloyd, set of publications of the Illuminating Engineering Society.

Dr. Caspar W. Miller, volumes of magazines on automobiles and horseless vehicles.

Philadelphia Book Company, books, pamphlets, and maps on various subjects.

Mr. Harrison Souder, engineering publications.

Spreckels' Sugar Refinery, volumes of the Official Gazette of the U. S. Patent Office.

Mr. Harrison D. Stratton, pamphlets on refrigeration.

Miss Wood, books on various subjects.

The executors of the estate of Mrs. W. H. Wahl, books, pamphlets, and maps from the library of the late William H. Wahl.

The U. S. Bureau of Standards, publications.

Mr. Joseph A. Arnold, Editor and Chief, Division of Publications, U. S. Department of Agriculture, has supplied the Library with copies of the current publications of the Department, and the Committee is indebted to him for the continuance of this courtesy.

DUPLICATES.

A number of duplicates have been received during the year from various sources, and the total stock at this time is 678 volumes. These will be used for exchange purposes, and the material so received will be added to the Library.

BINDING.

The total work done in the bindery was as follows:

	Bound	Rebound
Recent volumes of periodicals	328	
Recent volumes of periodicals charged to Chemical Periodical Binding Fund	26	
Old volumes	63	27
Books purchased with the income of the Moore Fund	4	1
Morris Fund	35	
Potts Fund	1	
	457	28
Total number of volumes		485

REPORT OF THE COMMITTEE ON MUSEUMS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

The Committee on Museums begs to report progress for the year ended September 30, 1914.

The following gifts have been received during the year and have been placed in charge of the Committee:

Model of J. P. Ross's Improved Reciprocating Engine, Lewisburg, Pa. Original adapted to blast furnaces and water works. Patented January 22, 1856. Model to scale of three-fourths inch to one foot. Gift of James C. Wobensmith, Esq.

Phantoscope, a motion-picture projecting machine, designed particularly for home use. Gift of Mr. C. Francis Jenkins, inventor.

Atwater Kent Ignition System, a system of battery ignition for automobile engines. Model consists of "Unisparker," distributer and spark-plugs mounted on stand. Gift of Mr. A. Atwater Kent, inventor.

Bronze Bust of Matthias W. Baldwin, manager of the Institute, 1827–1854; vice-president, 1855–1863. Bust modelled by Herbert Adams, New York, 1904, and cast by Aubry Brothers, New York; mounted on carved marble pedestal. Bequest of Mr. Francis T. Sully Darley.

Walnut Secretary Bookcase and Rug. Gifts of Miss Mary Thorn.

Several models have been received since the ending of the period this report covers, and mention of these will be included in the next report.

Respectfully submitted,

ALEX. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON MEETINGS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

During the year ending September 30, 1914, eight stated meetings were held.

At the May meeting the Elliott Cresson Medal was presented to Dr. Edgar F. Smith and to Dr. Orville Wright, two of the four scientists to whom this medal was awarded for distinguished achievement, the other two being Dr. Karl Ritter von Linde and Professor Dr. Josef Maria Eder. The presentations were made by President Walton Clark, and were followed by addresses from Dr. Smith and Dr. Wright.

Under arrangements made by your Committee, with the coöperation of the Secretary's office, papers were presented during the year as follows:

October 15, 1913.

"The Revolving Cylinder Internal Combustion Motor." Emile Berliner, Washington, D. C.

November 19, 1913.

"Producer Gas from Low-grade Fuels." R. H. Fernald, M.E., Ph.D., Consulting Engineer, U. S. Bureau of Mines; Whitney Professor of Dynamical Engineering, University of Pennsylvania, Philadelphia, Pa.

December 17, 1913.

"Petroleum and Its Derivatives." David T. Day, Ph.D., Department of the Interior, U. S. Geological Survey, Washington, D. C.

January 21, 1914.

"The Heat Received by the Earth from Stars and Planets." Ernest F. Nichols, Sc.D., LL.D., President, Dartmouth College, Hanover, N. H.

February 18, 1914.

"Artificial Daylight." Herbert E. Ives, Ph.D., Photometrical Laboratory, The United Gas Improvement Company, Philadelphia, Pa.

March 18, 1914.

"Marine Applications of Electricity." H. A. Hornor, B.A., New York Shipbuilding Company, Camden, N. J.

April 15, 1914.

"Researches in Metallurgy of Iron." A. S. Cushman, Ph.D., Director, Institute of Industrial Research, Washington, D. C.

May 20, 1914.

"Scientists from the Keystone State." Edgar F. Smith, Ph.D., Sc.D., LL.D., Provost, University of Pennsylvania, Philadelphia, Pa.

"Stability of Aëroplanes." Orville Wright, B.S., LL.D., Dayton, Ohio.

The above papers were referred to the Committee on Publications, and were afterwards, with the exception of one, published in the JOURNAL.

Dr. E. F. Northrup, Palmer Physical Laboratory, Princeton, N. J., was scheduled to address the stated meeting in March, but was unexpectedly unable to do so.

JAMES S. ROGERS,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON INSTRUCTION

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The courses offered in the ninetieth year of the Institute's School of Mechanic Arts, commencing in September, 1913, were substantially the same as those given in the preceding year, and the division of the instructional work into the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture was maintained.

The School opened on September 15, 1913, and during the year three hundred and twenty students were enrolled. This represented an increase of twenty over the preceding year and was the highest enrolment since the discontinuance of the Institute's Branch School at Germantown Junction in 1899. The largest classes formed were those in first-year Mechanical Drawing, in which eighty-nine students were enrolled, and in first-year Mathematics, to which fifty-eight students were admitted.

The faculty for the year was as follows:

Professor William H. Thorne, Director of the School, and in charge of the Department of Drawing.

Professor William E. Bullock, Assistant Director, and in charge of the Department of Mechanics.

Professor H. P. Tyson, in charge of the Department of Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

Professor Thorne was assisted in his Department by Professor Clement Remington, in charge of Architectural and Freehand Drawing, and by Messrs. F. H. Lobb, I. P. Pedrick, C. Rommel, and W. W. Twining, instructing in Mechanical Drawing.

Mr. W. A. Van Osten assisted in the Department of Mathematics, and Messrs. E. Bark and John F. Allison in Mechanics.

On November 15, 1913, Miss Mary Thorn, of Philadelphia, donated to the Institute a sum of money, the interest on which is to be used to provide free scholarships in the Departments of Mathematics, Mechanics, and Naval Architecture. By means of this gift, and also with the interest from the B. H. Bartol Fund, your Committee is now able to award free scholarships in all four Departments of the School.

During the season seven visits to manufacturing concerns were paid by students of the School, as follows:

Philadelphia Rapid Transit Company, Thirty-third and Market Streets Station, Philadelphia, Pa.
The Autocar Company, Ardmore, Pa.
The Commercial Museum, Philadelphia, Pa.
Hess-Bright Manufacturing Company, Philadelphia, Pa.
The Philadelphia Electric Company, Twenty-eighth and Christian Streets, Philadelphia, Pa.
United Gas Improvement Company, Experimental Department and Photometrical Laboratory, Philadelphia, Pa.
Bureau of Water, Torresdale Pumping Station, Philadelphia, Pa.

In every case the attendance was good and much interest was shown by those present. Our thanks are due to the managements represented for their courtesy.

A lecture, entitled "In Navajo Land," was delivered in the Hall of the Institute, by Mr. Frederick Monsen, F.R.G.S., on January 16, 1914, under the auspices of the Alumni Association. About two hundred students and friends were in attendance.

The attendance in the School throughout the year was well up to the average, and the work done was of exceptional merit in a large number of individual cases.

The graduating exercises were held in the Hall of the Institute on the evening of April 17, 1914. Dr. Walton Clark, President of the Institute, occupied the chair, and the graduating address was delivered by Dr. Gellert C. Alleman, Professor of Chemistry, Swarthmore College, Swarthmore, Pa. The Alumni Association was represented by Mr. J. C. Wobensmith. The annual report of the work of the School was presented by Professor Thorne. Forty-six students were graduated, seventeen in Mechanical Drawing, five in Architectural Drawing, two in Freehand Drawing, ten in Mathematics, six in Mechanics, and six in Naval Architecture. Twelve students in the Department of Drawing were the recipients of scholarships from the B. H. Bartol Fund, entitling them to free instruction. Six students were awarded free scholarships from the Isaac B. Thorn Fund. The student of greatest merit in the

Department of Mathematics was awarded a prize donated by Mr. J. B. McCall, President of The Philadelphia Electric Company. The student of greatest merit in the Department of Mechanics was also given a prize donated by Mr. Wilfred Lewis, President of the Tabor Manufacturing Company. A set of drawing instruments, offered by the New York Shipbuilding Company, was awarded to the student of greatest merit in the Department of Naval Architecture. Six graduates received awards provided by the Alumni Association of The Franklin Institute, and sixteen graduates making a perfect attendance record were awarded free membership for one year in the Association. In the Winter Term, thirty-nine students were awarded certificates of Honorable Mention; forty-four students received similar certificates in the Spring Term.

The graduates were invited to the annual smoker and luncheon of the Alumni Association, held on the evening following the exercises. At the luncheon ninety-eight covers were laid, and speeches were made by Dr. Walton Clark, Mr. George R. Henderson, and others.

In the summer of 1914, in preparation for the ninety-first year, a new School Calendar was issued. An attractive programme of visits to places of engineering interest for the new year was prepared. Valuable prizes were donated by Mr. J. B. McCall, Mr. Wilfred Lewis, the Alumni Association of The Franklin Institute, and the New York Shipbuilding Company, as in previous years, and by Mr. S. M. Vauclain, The Baldwin Locomotive Works, and Mr. W. D. Baldwin, The Otis Elevator Company, in addition. Announcements of these items were included in the Calendar.

In August, 1914, Hon. G. W. Edmonds, member of the Institute, offered to pay the tuition fees of five new scholars as an inducement to young men to enter the School. Mr. Edmonds's offer was accepted by the Committee, and an examination of young men was held and five scholars selected. Three of these are now studying in the Department of Drawing, one in Mathematics, and one in Mechanics.

The Committee on Instruction desires to express its appreciation to the individual members of the faculty for their earnest endeavor in their work, and wishes to congratulate them on the excellent results secured. The registration figures for the year, as well as for the previous year for comparison, follow:

	1912–13		1913–14	
	Winter Term, Sept.–Dec.	Spring Term, Jan.–Apr.	Winter Term, Sept.–Dec.	Spring Term, Jan.–Apr.
Drawing	158	132	188	148
Mathematics	61	39	71	57
Mechanics	38	23	30	20
Naval Architecture	29	23	17	15
	286	217	306	240

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

During the fiscal year ending September 30, 1914, there were one hundred and eleven members enrolled; resignations were received and accepted from thirty-one members; and deaths were recorded of twenty-six members.

The figures for the several classes of membership and for the two preceding years follow:

	1911–12	1912–13	1913–14
ELECTIONS:			
Resident Members	68	101	47
Non-Resident Members	33	186	57
Associate Members	7	1	7
Honorary Members	1	0	0
Life Members	1	3	0
	110	291	111
RESIGNATIONS:			
Resident Members	27	16	17
Non-Resident Members	13	13	12
Associate Members	1	2	2
	41	31	31
DEATHS:			
Resident Members	9	8	6
Non-Resident Members	4	4	4
Life Members	11	6	14
Honorary Members	1	1	2
Associate Members	1	0	0
	26	19	26

SUMMARY:		1913–14
Total Elections		111
Total Resignations	31	
Total Deaths	26	
		57
Net increase in membership		54

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

PROPERTY AND FUNDS.

Building and land, 13–17 South Seventh Street		$60,000.00	
Library		100,000.00	$160,000.00
	Principal	Unexpended Income	
Funds held by Board of Trustees	$280,843.37	$781.65	
Funds held by Board of Managers	23,481.65	56.69	
Franklin Institute Building Fund	363,924.31	.....	
Elliott Cresson Medal Fund	3,000.00	21.35	(overdrawn)
Franklin Fund and Building Committee	4,395.43	.....	
Total funds	$675,644.76	$816.99	676,461.75
Grand total			$836,461.75

LIABILITIES.

Certificates of stock	$30,370.00
Mortgage on Institute Building (held by Trustees as investment for funds)	30,575.00
Bills payable	20,250.00
Accounts payable	3,929.50
Unearned income	1,159.75
Grand total	$86,284.25

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

Income.

Dues		$11,048.17
Initiation fees		295.00
General Endowment Fund		9,388.90
James H. Cresson Memorial Fund		2,268.23
John Scott Medal Fund		375.00
Estate of John Turner		158.97
Estate of Robert Wright		1,615.55
Instruction: Drawing	$1,651.50	
Mathematics	629.50	
Mechanics	251.50	
Naval Architecture	213.50	2,746.00
Publications: Subscriptions and sales	$2,002.13	
Advertising	2,617.65	4,619.78
Total		$32,515.60

Expenses.

Building:	Wages	$1,212.75	
	Repairs and maintenance	421.71	
	Taxes, water rent, and insurance	409.27	
	Heat, light, and power	784.80	
	Miscellaneous supplies and expense	249.35	$3,077.98
Elections and resignations			143.69
Instruction:	Drawing	$1,321.20	
	Mathematics	302.50	
	Mechanics	277.04	
	Naval Architecture	220.00	
	Miscellaneous expense	870.30	
	Popular lectures	76.98	3,068.02
Library:	Salaries	$4,028.45	
	Books and periodicals	1,575.92	
	Binding	750.35	
	Miscellaneous expense	239.41	6,594.13
Meetings			444.06
Office and General:	Salaries	$8,770.32	
	Office expense	816.09	
	General expenses	1,176.03	10,762.44
Publications:	Printing	$6,077.21	
	Reprints	829.35	
	Illustrating	710.96	
	Miscellaneous expense	611.79	
	Year-Book	450.00	8,679.31
Science and Arts			1,623.78
Sections			1,128.49
Basement renovation			372.95
Fire protection improvements			1,666.22
Interest and discount			1,394.34
Membership badges			84.68
Miscellaneous income and expense			469.25
Total			$39,509.34
Deficit			6,993.74

During the fiscal year there has been an increase in funds as follows:

General Endowment Fund	$10,300.00
Elizabeth M. Graff Fund	14.90
Franklin Medal Fund *	5,000.00
Isaac B. Thorn Scholarship Fund *	1,000.00
Franklin Institute Building Fund	7,260.85†

The mortgage on the Institute building has been increased by $9250. Bills payable have been decreased by $2000.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON PUBLICATIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The policy recently adopted by the Committee on Publications and duly sanctioned by the Board, directed to the purpose of making the publications of the Institute adequately expressive of its scope and activities, has been consistently pursued during the past year. The JOURNAL OF THE INSTITUTE, particularly, as its recognized exponent, has accordingly been developed as fully as conditions would permit, and the Committee has given all possible support to the efforts of the editor and of our editorial collaborators in this direction. The transactions of the Institute, of its various Sections and of its Committee on Science and the Arts, published from month to month in the JOURNAL, have continued to be supplemented by the series of important communications, inaugurated last year, from the U. S. Bureau of Standards, and by a number of very valuable papers from our associate editors. To the list of these latter has been added during the past year the name of our esteemed fellow-member of the Institute, Professor Gaetano Lanza, of the engineering department of The Baldwin Locomotive Works. The very welcome service rendered to the Institute by the distinguished authorities who are giving us their coöperation in the editorial conduct of the JOURNAL is gratefully acknowledged by your Committee.

The distinctions provided in recognition of especially important papers published in the JOURNAL during the year 1913 were awarded to their respective authors by the Committee on Science and the Arts at its May stated meeting. Details of these awards are included in the report of that Committee.

The Year-Book of the Institute, in its improved form and thoroughly revised, was duly published in October, and has been appreciatively received by the membership.

The cost of the work carried on by the Committee in the fiscal year ending September 30, *ultimo,* was $8679.31, of which $7617.52 appertains to the

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* New funds.

† Decrease, due to loss on securities sold to purchase site.

JOURNAL, $450 to the Year-Book, and $611.79 to extraneous expenses. The income from the JOURNAL through subscriptions, sales, and advertising accounts was $4619.78, leaving a debit balance of $4059.53. Inasmuch as the JOURNAL and Year-Book are furnished to all members of the Institute as among the privileges of membership, a fair proportion of the membership dues may properly be credited to the item of publication, in which case the account would be practically balanced.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON EXHIBITIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers of The Franklin Institute:

There have been no developments since the last report of the Committee which would encourage the expectation of an exposition in the near future, except in the fact that a temporary building and annexes have been permitted on the Parkway near Vine Street. This indicates that similar facilities may be secured by the Institute, as suggested in the last report. It is questionable whether the present structure would be suited for exposition purposes, for it is primarily an auditorium.

One exposition in southern California has opened for the year, and the one at San Francisco will soon be in operation, and until these are accomplished facts and the character of the exhibits known the desirability of having some of them on display in Philadelphia subsequently to the other exhibitions need not be considered.

Therefore your Committee would report progress.

JOHN BIRKINBINE,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The Committee on Sectional Arrangements takes pleasure in reporting that nineteen lectures were delivered during the year ending September 30, 1914, as follows:

PHYSICS AND CHEMISTRY SECTION—*Six Meetings.*

November 6, 1913.

"The Present State of our Knowledge of Solution." Harry C. Jones, Ph.D., Professor of Physical Chemistry, Johns Hopkins University, Baltimore, Md.

November 13, 1913.

"High Pressures and Five Kinds of Ice." P. W. Bridgman, A.M., Jefferson Physical Laboratory, Harvard University, Cambridge, Mass.

January 8, 1914.

"Physics of the Sun—A Review of Recent Solar Research." C. G. Abbott, S.M., Smithsonian Institution, Washington, D. C.

January 29, 1914.

"Advantages and Disadvantages of Water Storage." W. P. Mason, C.E., M.D., LL.D., Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.

February 11, 1914.

"The Biochemistry of Soil Fertility." Oswald Schreiner, Ph.D., U. S. Department of Agriculture, Washington, D. C.

March 5, 1914.

"By-products of Coal." L. C. Jones, Ph.D., The Solvay Process Company, Syracuse, N. Y.

ELECTRICAL SECTION—*Four Meetings.*

October 2, 1913.

"Effect of Electrical Engineering on Modern Industry." Charles P. Steinmetz, Ph.D., Electrical Engineer, General Electric Company, and Professor of Electrical Engineering, Union College, Schenectady, N. Y.

October 23, 1913.

"High-voltage Engineering." F. W. Peek, Jr., Consulting Engineer, General Electric Company, Schenectady, N. Y.

April 9, 1914.

"Recent Developments in the Art of Illumination." Preston S. Millar, Electrical Testing Laboratories, New York City.

April 23, 1914.

"Recent Developments in Hyperbolic Functions as Applied in Electrical Engineering." A. E. Kennelly, Sc.D., Professor of Electrical Engineering, Harvard University, Cambridge, Mass.

MECHANICAL AND ENGINEERING SECTION—*Seven Meetings.*

November 25, 1913.

"Recent Developments in Aëromechanics." A. F. Zahm, M.E., Ph.D., Washington, D. C. (Joint meeting with the Aëro Club of Pennsylvania.)

December 11, 1913.

"The Catskill Water Supply for New York City." J. Waldo Smith, C.E., Chief Engineer, Board of Water Supply, New York City.

January 15, 1914.

"Sewage Treatment." Rudolph Hering, Consulting Engineer and Sanitary Expert, New York City.

February 26, 1914.

"The Valuation of Public Utility Properties." M. E. Cooley, D.Eng., LL.D., Dean of the Department of Engineering, University of Michigan, Ann Arbor, Mich.

March 26, 1914.

"Recent Progress in Military Aëronautics." Col. Samuel Reber, U. S. A., New York City. (Joint meeting with the Aëro Club of Pennsylvania.)

April 2, 1914.

"Some Engineering Problems in Sanitary Science." J. A. Vogleson, Chief of the Bureau of Health, City of Philadelphia.

April 30, 1914.

"Locomotive Superheaters and Their Performance." C. D. Young, Engineer of Tests, Pennsylvania Railroad, Altoona, Pa. (Joint meeting with the American Society of Mechanical Engineers.)

MINING AND METALLURGICAL SECTION—*Two Meetings.*

October 30, 1913.

"The Making of Sound Steel Ingots." Bradley Stoughton, Ph.B., Consulting Metallurgical Engineer, New York City.

December 4, 1913.

"Some Present-day Metallurgical Processes." D. A. Lyon, A.M., Pittsburgh, Pa., Representative in United States, Canada, and Mexico of Electro-Metals, Ltd., London, England. (Joint meeting with the American Institute of Electrical Engineers.)

SECTION OF PHOTOGRAPHY AND MICROSCOPY—*No Meetings.*

It will be noted that four joint meetings were held, one with the American Society of Mechanical Engineers, one with the American Institute of Electrical Engineers, and two with the Aëro Club of Pennsylvania.

The attendance at meetings shows a gratifying increase, the average being about 170 for the period covered by this report.

The lectures were all illustrated by lantern slides, and in many instances special apparatus and exhibits were introduced. Most of these lectures were published in the JOURNAL.

CHARLES DAY,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON ENDOWMENT

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the Board of Managers:

The subscriptions to meet the conditions of the Wahl bequest to The Franklin Institute to date are as follows:

Promises to subscribe	$15,795.00
Cash on deposit at the Girard Trust Co.	485.00
Total	$16,280.00

Some determined effort must shortly be made to secure the balance of the amount necessary to meet the conditions of the Wahl bequest, and, as the suggestion was made in Dr. Wahl's will that any subscription by an individual, the City of Philadelphia, or the State of Pennsylvania, would meet the requirements, your Committee proposes that a bill be introduced at the next meeting of the State Legislature appropriating a certain amount for the use of The Franklin Institute.

It is the opinion of the Committee that each member of the Institute should make himself a Committee of One to secure subscriptions during the next year to the Wahl Fund, whether the subscriptions are large or small.

As set by Dr. Wahl's will, the time limit for securing these subscriptions will expire December 16, 1916.

During the year 1914 the Institute received Ten Thousand Dollars ($10,000) from the executors of the estate of Anna Blanchard, deceased, and also received notice that it is one of the residuary legatees of the estate of the late Miss Elizabeth S. Shippen.

In connection with the John Scott Medal Fund, the Board of City Trusts has appropriated an allowance of Nine Hundred Dollars ($900) annually for expenses.

Respectfully,

HENRY HOWSON,
Chairman.

PHILADELPHIA, January 13, 1915.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1914.

To the President and Members of The Franklin Institute:

Your Committee on Science and the Arts investigated and disposed of forty-two cases during the year.

Ten stated meetings were held, as provided for in the Regulations. The average attendance was 23.4, or fifty per cent. above the quorum necessary for all actions on reports. At no meetings were there less than twenty members present.

At the April meeting the Secretary announced that Mr. Samuel Insull, of Chicago, Ill., had founded The Franklin Medal Fund, that his gift had been accepted by the Board of Managers of the Institute, and that the following deed had been duly executed and delivered:

> KNOW ALL MEN BY THESE PRESENTS, That The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, hereinafter named The Franklin Institute, for and in consideration of the sum of Six Thousand Dollars ($6000) to it in hand paid by Samuel Insull, Esq., the receipt whereof is hereby acknowledged, does hereby certify and declare that it holds and will use said sum of money for the following uses, intents, and purposes, and upon the following perpetual trusts, that is to say:

1. To expend One Thousand Dollars ($1000), or so much thereof as may be necessary, for the purpose of paying for the design of a medal, and the necessary dies and diploma plates for the purposes hereinafter set forth.

2. To invest and keep invested the balance of said sum, and from the income derived from such investments from time to time to strike off and award medals from said design to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of said The Franklin Institute, have done most to advance our knowledge of physical science or its application. Should the income derived from this fund be more than necessary for the purposes aforesaid, the said The Franklin Institute may, in its discretion, award so much of the surplus as its Board of Managers deems wise, as premiums to accompany said medals.

3. The fund thus set apart shall be known as "The Franklin Medal Fund" (founded January 1, 1914, by Samuel Insull, Esq.).

4. The medals to be awarded as aforesaid shall be of gold, shall have distinct artistic merit, shall be of the intrinsic value of about Seventy-five Dollars ($75), and shall have on one side thereof a medallion of Benjamin Franklin taken from his portrait by Thomas Sully, now in the possession of the said The Franklin Institute.

IN WITNESS WHEREOF, The said The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts has hereunto set its common or corporate seal, attested by the signatures of its President and Secretary, this 28th day of March, A.D. 1914.

[SEAL]

WALTON CLARK,
President.

R. B. OWENS,
Secretary.

A sub-committee was appointed to draw up the necessary amendments to the Regulations. This sub-committee reported at the June meeting, and its report, recommending the appointment each year of a sub-committee to make recommendations for awarding this medal, was adopted at the September meeting.

At the February meeting resolutions were framed petitioning the Board of Directors of City Trusts of the City of Philadelphia for further financial assistance to meet the costs of investigating applications for the John Scott Medal. These resolutions were communicated to the Board of Directors of City Trusts, and the latter gave consideration to them and adopted the following resolution at its May meeting:

RESOLVED, That The Franklin Institute be paid the sum of Nine Hundred Dollars ($900) per annum, from May 1, 1914, to reimburse it for expenses incurred in the investigation and applications for medals from the John Scott Medal Fund.

The resignation of Professor Haupt was received at the February meeting with regret. A sub-committee was appointed which drafted resolutions expressing the sentiments of the Committee. These resolutions were engrossed and presented to Professor Haupt, and a copy of them was published in the April issue of the JOURNAL.

Amendments to the Regulations proposed by Mr. L. E. Levy and Mr. H. F. Colvin were considered and adopted in their final form.

The Regulations incorporating all the amendments as above were included in the 1914 Year-Book of the Institute, published in October.

In accordance with the recommendation of the former chairman of this Committee, Mr. Crisfield, an amendment replacing the Sub-committee on New Subjects and Publicity and the Sub-committee on Preliminary Examination by a Sub-committee to be known as the Sub-committee on New Subjects and Preliminary Examination, was adopted at the March meeting. This sub-committee has since held one meeting before each stated meeting. During the year it received eleven applications and considered twenty-five subjects, five of which were recommended for investigation.

Appended to this report is a detailed statement of the operation of the Committee for the year. The number of awards recommended by standing sub-committees and sub-committees of investigation as the result of their labors is indicated below:

SUB-COMMITTEE ON LITERATURE.

Number of Potts Medals recommended 1
Number of Longstreth Medals recommended 3

SUB-COMMITTEE ON ELLIOTT CRESSON AWARDS TO DISTINGUISHED SCIENTISTS AND TECHNOLOGISTS.

Number of awards recommended 4

SUB-COMMITTEES ON INVESTIGATIONS.

Number of awards recommended 17

A detailed list of the awards made during the year is also appended.

Your Committee has now adopted the practice, recommended also by the former chairman, of holding an informal dinner prior to each meeting. The average attendance at these functions was twelve members.

During the year medals awarded to inventors who were able to attend stated meetings of the Institute have been presented to them by the President.

In order to still further advance the usefulness of the work of this Committee, a recommendation made a year ago is reiterated as follows: That there should be some more widespread method of bringing before the public

the Committee's facilities for reporting upon applications, and the fact stated that such investigations are made without charge. It is believed, in this connection, that the coöperation of other engineering, scientific, and educational bodies can be secured and our efforts to encourage inventive genius and original research made more effective. The JOURNAL OF THE INSTITUTE alone cannot accomplish all that is desired in this direction.

It is also believed that the time is propitious for the Committee, acting in accordance with its power and on behalf of the Institute, to call attention to the facilities it possesses for reporting upon matters of public or semi-public interest. The records of the Committee contain many examples of the exercise of this function in the past, such as, for instance, its report upon the Standardization of Screw Threads, the Manayunk Intercepting Sewer, the Abatement of the Smoke Nuisance in Philadelphia, etc. The bringing of our facilities in this connection to the proper notice may probably best be accomplished by the appointment of a standing sub-committee to receive requests for, and to formulate, opinions upon questions of this character. The State and municipal departments, for example, would no doubt be glad to receive and acknowledge help of this kind. In this way the work of the Committee would be made of greater benefit to the community at large. In former times our public officers freely consulted the Institute upon matters in question, and in many cases the Committee was able to render services to them, an honor which was greatly appreciated by its members, and a pleasurable duty.

In conclusion, it should be stated that the work of the past year has been of great interest, not only in consideration of the subjects received, but also of the eminent and able men to whom awards have been made, and of the appreciation of our efforts by these recipients.

Respectfully submitted,

GEORGE R. HENDERSON,
Chairman.

PHILADELPHIA, January 13, 1915.

APPENDIX.

STATEMENT OF THE COMMITTEE'S OPERATION FOR THE YEAR ENDED SEPTEMBER 30, 1914.

CASES.

Cases pending, October 1, 1913		23
Applications during the year	26	
Special reports	9	
	—	35
		58
Disposed of during the year		42
Leaving pending		16

DISPOSITION OF CASES.

Elliott Cresson Awards	6
Howard N. Potts Awards	1
Edward Longstreth Awards	6
John Scott Legacy Recommendations	11
Certificates of Merit	1
	25

AWARDS MADE DURING THE YEAR.

THE ELLIOTT CRESSON MEDAL.

Josef Maria Eder, Ph.D., of Vienna, Austria, in recognition of his important original researches in the science of photochemistry and his many valuable contributions to the literature of that science and of the graphic arts.

Wolfgang Gaede, of Freiburg-in-Bresgau, Germany, for his Molecular Air Pump.

Peter Cooper Hewitt, Sc.D., of New York, N. Y., for his Mercury Arc Rectifier.

Professor Karl Ritter von Linde, Ph.D., of Munich, Germany, in recognition of his scientific investigations of the processes of refrigeration and the liquefaction of gases, and of his inventions of machinery for applying these processes in the manufacture of ice and for the purposes of cold storage.

Professor Edgar Fahs Smith, Ph.D., Sc.D., LL.D., of Philadelphia, Pa., in recognition of his leading work in the field of electrochemistry, of his many contributions to the literature of chemical science, and of his great service in university education.

Orville Wright, B.S., LL.D., of Dayton, Ohio, in recognition of the epoch-making work accomplished by him, at first together with his brother Wilbur and latterly alone, in establishing on a practical basis the science and art of aviation.

THE HOWARD N. POTTS MEDAL.

Ralph Modjeski, D.Eng., of Chicago, Ill., for his paper on "Design of Large Bridges, with Special Reference to the Quebec Bridge," in the September, 1913, issue of the JOURNAL.

THE EDWARD LONGSTRETH MEDAL.

H. T. Herr, of Pittsburgh, Pa., for his paper on "Recent Developments in Steam Turbines," in the February, March, April, May, and June, 1913, issues of the JOURNAL.

Hiram H. Hirsch, of Philadelphia, Pa., for his Electric Safety Lamp.

Wm. J. Humphreys, Ph.D., of Washington, D. C., for his paper on "Volcanic Dust and Other Factors in the Production of Climatic Changes, and Their Possible Relation to Ice Ages," in the March, 1913, issue of the JOURNAL.

Kinkead Manufacturing Company, of Boston, Mass., for their Apparatus for Aligning and Levelling Shafting.

John M. Rusby, of Philadelphia, Pa., for his paper on "Industrial Combustible Gases," in the July, 1913, issue of the JOURNAL.

Johann Stumpf, of Charlottenburg, Germany, for his Una-Flow Steam Engine.

THE CERTIFICATE OF MERIT.

Ellis B. Ridgway, of Coatesville, Pa., for his Steam Hydraulic Elevator.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Charles S. Batdorf, of New York, N. Y., for his Coin Counting and Wrapping Machine.

Halcolm Ellis, of Newark, N. J., for his Adding-Typewriter.

C. E. Guillaume, Ph.D., of Sèvres, France, for his alloy Invar.

Aldus C. Higgins, of Worcester, Mass., for his Electric Furnace in which Alundum is made commercially.

Charles B. Jacobs, of New York, N. Y., for his Process of Producing a New Abrasive and Refractory Material.

C. Francis Jenkins, of Washington, D. C., for his Motion-picture Apparatus.

Jesse W. Reno, of New York, N. Y., for his Inclined Elevator or Escalator.

Allen A. Tirrill, of Pittsburgh, Pa., for his Automatic Potential Regulator.

Adolph Spielman, of Philadelphia, Pa., for his Cloth-cutting Machine.

JOHN SCOTT MEDAL RECOMMENDATIONS.

(*Awards pending, September 30, 1914.*)

A. Atwater Kent, of Rosemont, Pa., for his Unisparker.

Elmer A. Sperry, of New York, N. Y., for his Gyro-Compass.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, January 6, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 6, 1915.

MR. GEORGE R. HENDERSON *in the Chair.*

The following reports were presented for first reading:

No. 2620.—Adamite. Advisory. Adopted.

No. 2621.—Wahl Adding Machine.

The following report was presented for final action:

No. 2624.—Vanier's Potash Bulb. Certificate of Merit. Adopted.

R. B. OWENS,
Secretary.

AWARD OF THE JOHN SCOTT MEDAL.

The CITY OF PHILADELPHIA, acting on the recommendation of The Franklin Institute, has awarded the John Scott Legacy Medal and Premium to Charles Edouard Guillaume, of Sèvres, France, for his alloy Invar. This alloy contains approximately 63.8 per cent. iron and 36.2 per cent. nickel. It is characterized by possessing an extremely small coefficient of linear expansion, about 0.0000004 per degree Centigrade. Within the limits of atmospheric

temperature change its expansion is very exactly proportional to the temperature. It has a modulus of elasticity of about two-thirds that of steel, and its hardness is greater than that of hard brass. Invar has found a wide application in metrology and in horology. In the former it is particularly useful for secondary standards of length, and in the latter it is employed for pendulum rods, compensating devices for torsion pendulums and balance wheels correcting the secondary error of temperature in chronometers.

AWARD OF THE CERTIFICATE OF MERIT.

MR. GEORGE P. VANIER, of Steelton, Pa., has been awarded a Certificate of Merit for his Potash Bulb. This bulb has been particularly designed for use in the determination, in industrial laboratories, of the total carbon in iron or steel. In such laboratories time is often a very important factor. The bulb is of large capacity, and, by the provision of a glass spiral in which the gases of combustion of the sample under test and the potash solution circulate together, a high rate of absorption of carbonic acid is obtained. With the bulb is combined a drying tube.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, January 7, 1915, at 8 P.M. Mr. George R. Henderson presided. The minutes of the previous meeting were approved as published.

The Chairman introduced Mr. Wm. H. Connell, Chief, Bureau of Highways and Street Cleaning, City of Philadelphia, who presented a communication, entitled "The Organization, Character of Personnel, Scope of Work, and Methods of Operation and Control of a Large Municipal Highway Department." In his remarks the speaker considered the construction and maintenance of highways, the laying out of parks and parkways, street cleaning, collection of ashes, garbage and refuse, and the general work coming under the jurisdiction of a Bureau of Highways. By means of lantern slides he illustrated modern appliances for and methods of performing the work of such a bureau, and the results secured by efficient organization.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting-Secretary.

Mining and Metallurgical Section.—A joint meeting of the Philadelphia Section of the American Society of Mechanical Engineers and the Mining and Metallurgical Section of the Institute was held in the Hall of the Institute on Thursday, January 14, 1915, at 8 P.M.

Professor H. E. Ehlers and Professor A. E. Outerbridge, Jr., presided.

Professor Outerbridge introduced Mr. Robert R. Abbott, B.S., E.M., Metallurgical Engineer, the Peerless Motor Car Company, Cleveland, Ohio, who presented a communication, entitled "Modern Steels and Their Heat Treatment." After considering the mixtures and compounds of iron and

carbon present in steels, the proportions of these contained in steels of different carbon contents, and their influence upon the strength of the material as indicated by percentage reduction in area in tension, the speaker described the effect upon the iron-carbon constituents produced by alloying with the iron other elements, such as nickel, chromium, manganese, etc. He then compared with this latter the effects produced by heat treatment, showing that such effects were practically the same as those produced by alloying. He concluded with an outline of the commercial applications of heat-treated steel. The speaker illustrated his remarks by means of lantern slides of photomicrographs and charts.

The paper was discussed by Professor A. E. Outerbridge, Jr., Professor E. Marburg, Mr. H. V. Wille, Dr. Carl Hering, and others.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting-Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, January 13, 1915*).

RESIDENT.

PROF. H. JERMAIN MAUDE CREIGHTON, Swarthmore College, Swarthmore, Pa.

MR. JOHN S. ROOKE, Edw. Harrington Son & Co., Seventeenth and Callowhill Streets, Philadephia, Pa.

MR. CLARKE THOMSON, 526 Land Title Building, Philadelphia, Pa.

NON-RESIDENT.

MR. LYLE STOCKTON ABBOTT, 281 Newfield Street, East Orange, N. J.

MR. R. R. M. CARPENTER, Wilmington, Del.

MR. W. W. COE, Pocahontas Coal and Coke Company, Roanoke, Va.

MR. EDWARD HEITMANN, Can. Crocker-Wheeler Company, St. Catharines, Ont.

PROF. I. M. RAPP, Ursinus College, Collegeville, Pa.

CHANGES OF ADDRESS.

MR. F. M. MASTERS, Chief Inspector, No. 9 North Front Street, Harrisburg, Pa.

MR. WILLIAM M. SCOTT, Box 76, Radnor, Pa.

MR. JOHN R. TITZEL, Gas Engineer, 61 Broadway, New York, N. Y.

NECROLOGY.

Theodore Armstrong was born in New York, N. Y., in 1840. In 1861 he enlisted in the Union Army, in which he served with distinction. In 1864 he became auditing clerk in the internal revenue office in Philadelphia, and in the following year he accepted the position of chief accountant at the Pennsylvania Salt Company's Natrona factory. He was later made secre-

tary of this company in Philadelphia, then vice-president, and in 1888 was elected president, serving in that capacity for many years. He was a member of the Union League, the Manufacturers' Club, the American Chemical Society, and other prominent organizations. He was elected to membership of The Franklin Institute in 1903.

William Penn Evans was born in Bridgeport, Pa., and received his technical education in the Polytechnic College, Philadelphia, Pa.

His first work was with R. S. Newbold & Son, the Eagle Iron Works, Norristown, Pa. He left the Eagle Iron Works in September, 1872, to accept a position with The Baldwin Locomotive Works, in the Drafting Department, and he continued service with this company, with the exception of a brief interval, until the time of his death. In 1876 he obtained a leave of absence to act as Assistant Superintendent of the Philadelphia and Reading Terminal at the Centennial Exposition, and in 1879 he left The Baldwin Locomotive Works to accept the position of Mechanical Engineer of the Missouri, Kansas and Texas Railroad, at Sedalia, Mo. After one year's service, he returned to The Baldwin Locomotive Works and was appointed Chief Draftsman in 1885, which position he held until 1903. In 1904 he was placed in charge of the exhibit of The Baldwin Locomotive Works at the Louisiana Purchase Exposition at St. Louis, Mo., and upon his return to Philadelphia at the termination of the Exposition was made General Night Superintendent. In 1905 he was given charge of the exhibit of The Baldwin Locomotive Works at the Lewis and Clark Exposition at Portland, Ore., and when this exhibit was closed was appointed Northwestern Agent, with headquarters at Portland, Ore. He continued in this position until 1910, when he returned to Philadelphia and was appointed General Inspector, which position he held until the time of his death.

He was a member of the American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Historical Society of Pennsylvania. He was elected to membership in The Franklin Institute in 1897, served on its Committee on Science and the Arts from 1898 to 1900, and was appointed Chairman in the latter year.

Henry Gurney Morris was born in Philadelphia, Pa., in 1839. He was graduated from Haverford College and became a member of the firm of Morris, Tasker & Co., the first manufacturers of iron pipes in Philadelphia. He later became owner of the Southwark Foundry and a director of the Pennsylvania Steel Company. He was the patentee of a number of mechanical and electrical inventions, including centrifugal machines, brick moulding and pressing machines, centrifugal mixers, electric fans, storage batteries, and electric vehicles. In collaboration with Pedro G. Salom, he made a number of valuable contributions to the development of the horseless vehicle some twenty years ago. He was a member of the American Society of Mechanical Engineers, the American Society of Mining Engineers, and the American Society of Civil Engineers. He was also associated with the Union League and the Engineers' Club of Philadelphia. He was elected to life membership of The Franklin Institute in 1861, served on its Board of Managers from 1864 to 1869, and was vice-president from 1870 to 1879.

WILLIAM PENN EVANS

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CORRESPONDENCE.

THE UNIVERSITY OF NEBRASKA,
LINCOLN.

DEPARTMENT OF ELECTRICAL ENGINEERING.
OLIN J. FERGUSON, *Professor.*
V. L. HOLLISTER, *Associate Professor.*
IVAN M. KIRLIN, *Instructor.*

December 29, 1914.

R. B. OWENS, Editor,
Philadelphia, Pa.

DEAR SIR:

The papers by Dr. Humphreys upon "The Thunderstorm and Its Phenomena" have interested me very much, and I wish to offer a comment upon the matter of beaded lightning, which subject he mentions in the December number of the JOURNAL, page 764.

In the spring of 1914 a violent thunderstorm swept over Lincoln at about nine o'clock at night. There were numerous vivid lightning displays. One of these discharges occurring in the storm front originated at an elevation of about 45 degrees from my viewpoint and struck almost vertically downward. I was watching the storm from the window of a dark room, and the flash occurred directly in front of me. It was a direct stroke of chain or streak lightning.

However, in dying away, it took probably a full second to disappear, and in doing so it broke up seemingly into detached portions, short and numerous. In fact, it gave a bead-like effect, and it would be very easy for one to have retained the latter impression and to have called the stroke bead lightning.

In explanation of this phenomenon I would suggest that each bead probably represents the "end-on" view of the irregular portions of the lightning path, and that they remained luminous during the subsequent lesser discharges, while the intermediate sections became non-luminous, because viewed from the side. This theory is borne out by photographs taken with the rotating camera, where it is evident that the later discharges are not necessarily of as great an intensity as the primary discharge. Fig. 25 in Dr. Humphreys's paper illustrates this well, and I have negative and photographs in my possession which show the same plaid ribbon effect.

I also have three negatives where the so-called dark discharge is evidenced in very short strokes. Granting that this is explainable by the photographic reversal of an overexposure, I do not see why it is necessary to conclude that there is no such thing as a dark discharge. It is the fact that visibility occurs only within a very narrow range of frequencies, and, inasmuch as we do not see the electric discharge itself anyway, it is quite conceivable that a discharge may occur and give rise to phenomena quite different in frequencies from those of visible light, and that these phenomena may affect the photographic plate in the manner noted.

You will note that I am advancing no data or experimental proof for this latter statement. This is because I have none and am simply theorizing. However, I see nothing inconsistent in my line of thought.

Very sincerely yours,

O. J. FERGUSON.

BOOK NOTICES.

MECHANICAL LABORATORY METHODS. By Julian C. Smallwood, M.E., Associate Professor Experimental Engineering, Syracuse University. New York, D. Van Nostrand & Company, 1914. 333 pages, 95 illustrations, 12mo. Price, $2.50.

In attempting to describe his book, the author, in the preface, says that he "finds thoughts uppermost of what it is intended not to be," and follows by stating that he does not attempt to cover all the instruments or methods of any class, and he expects the students, for whom the work has been especially prepared, to know the principles and purposes of the various instruments used in the tests before starting to work with them.

One of the first principles announced is the comparative worthlessness of *single determinations,* and he then states that "it is only by repeated trials that accurate conclusions can be framed." This is a very important point for beginners, and it is fortunate to have this axiom so clearly stated, in order to guard against immature reports. The care that should be given to proper calibration of instruments prior to their use is prominently set forth and especial attention is called to points in this preparatory work that are likely to be overlooked. As an example of this may be quoted the 18 pages devoted to the corrections needed to overcome the irregularities in the drum motion of steam engine indicators. The calibration of "flow meters" also occupies 34 pages.

Part 2, on fuel and combustion, is very complete and interesting, and treats of solid, liquid and gaseous fuels in boilers and internal-combustion engines.

In his section on friction tests no mention is made of the elaborate brake-shoe tests of the Master Car Builders' Association, nor of any of the special methods used in this work. Nor is locomotive testing referred to, although this requires quite a different treatment from stationary boilers and engines.

In connection with the ordinary methods of obtaining the clearance volume of steam engine cylinders, the Clayton method is referred to, although it is recommended only where the clearance is large, as in internal-combustion engines. In steam engines it would be hardly expected to give accurate results, as the condensation and re-evaporation during expansion would destroy the accuracy of the PV curve. He treats of this also under steam consumption for determining the quality of steam at cut-off, but says that this method has not been sufficiently verified for general application, which indicates that it should be used with caution until further developed. We think that this is sound logic, and that the more accurate methods should be followed, even if more laborious.

In his chapter on making reports of tests, he states that when it is not considered necessary to furnish tables in full a sample set may be submitted. It seems to the writer, however, that full reports are always desirable, even if placed in the appendix, as at a later date it may be desirable to glean from the tests some conclusions not considered necessary when the test was made. It is for this reason that the reports from the Pennsylvania Railroad Testing Plant are so valuable, as many lines of study can be made from them not specifically investigated in connection with the published reports.

In conclusion, we believe that the book will be found useful to those for whom it is intended; the style is good and the typography clear.

GEORGE R. HENDERSON.

LABORATORY MANUAL FOR THE DETECTION OF POISONS AND POWERFUL DRUGS. By Dr. William Autenrieth, University of Freiburg i. B. Translated by W. H. Warren, Ph.D. Fourth edition. Philadelphia, P. Blakiston's Son & Company, no date. 315 pages, 25 illustrations, index and table of contents, 8vo. Price, $2.

A fourth edition usually offers to the reviewer little opportunity for new criticism, but the translator of this work tells us that much new matter has been added and the text somewhat rearranged.

The work is a comprehensive and convenient guide to the toxicologist, including, as it does, a long list of poisons and the modern qualitative and quantitative procedures. The reviewer cannot forbear to say that the time seems now to be past in which American analysts need to rely for general text-book assistance on European authorities. The procedures in toxicology, industrial analysis, and examination of food and drugs that have been developed by American workers are in all respects as satisfactory as those

that come from abroad, though, of course, long established—so-called "classic"—methods are still important, but these are available in all text-books. It is to be hoped that the translator of this volume or some equally competent American chemist will soon furnish us with a "made in America" manual.

A notable and useful addition to the present work, contributed by the translator, is a discussion of the so-called "normal" arsenic; that is, the existence of arsenic in the human body as an essential constituent. Dr. Warren rightly objects to the word "normal" in this connection, and from an extended study of the literature comes to the view that the likelihood of arsenic being naturally in the body is too remote to concern the practical toxicologist.

The reviewer thinks that the numerous structural formulas in the book are out of place. The work is a laboratory manual, not an introduction to organic chemistry.

HENRY LEFFMANN.

OPTIC PROJECTION: Principles, Installation, and Use of the Magic Lantern, Projection Microscope, Reflecting Lantern, and Moving-picture Machine. By Simon Henry Gage and Henry Phelps Gage, Ph.D. Ithaca, N. Y., The Comstock Publishing Company, 1914. 703 pages, index, plates and illustrations, 8vo. Price, $3.

This work fills a great want. The enormous increase in the use of projection methods in the class-room, as well as in public lectures, has rendered necessary some comprehensive account of the principles underlying the several systems, and of the methods for securing the best results. The commercial production of electricity and the advance in high-speed photography have greatly increased the facilities for obtaining and projecting lantern slides; the perfecting of the opaque projection and the motion-picture apparatus has added extensive fields of illustration.

The principles on which projection apparatus is constructed and operated are far from simple, and much of the information has been obtainable only from foreign sources or from manufacturers' catalogues. It is, therefore, of much value to American teachers that a book of comprehensive character and independent attitude is presented. The theory and practice of all phases of projection apparatus are fully explained and the dangers and difficulties of operation are set forth.

The work will have a large sale, and the first edition will soon be exhausted. The reviewer desires to call attention to a defect which it is hoped that the authors will note and avoid in subsequent editions. The book is greatly over-illustrated. The topics are mostly such as need illustration, but it is mere trifling to insert full-page pictures from manufacturers' catalogues. The use of a great many half-tones renders a heavy paper necessary, making the book cumbersome. An equally satisfactory consideration of all topics could have been presented with half the illustrations.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 77, The Electric Furnace in Metallurgical Work, by Dorsey A. Lyon, Robert M. Keeney, and Joseph F. Cullen. 216 pages, illustrations, 8vo. Technical Paper 94, Metal-mine Accidents in the United States during the Calendar Year 1913, compiled by Albert H. Fay. 73 pages, 8vo. Fourth Annual Report of the Director of the Bureau for the Fiscal Year Ended June 30, 1914. 101 pages, 8vo. Washington, Government Printing Office, 1914.

Canada Department of Mines, Mines Branch: Gypsum in Canada: Its Occurrence, Exploitation, and Technology, by L. H. Cole. 256 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1913. The Production of Coal and Coke in Canada during the Calendar Year 1913, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 40 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

Armour Institute of Technology: Bulletin, May, 1914, General Information Number. 199 pages, plate, 8vo. Chicago, Institute, 1914.

University of the State of Iowa: Bulletin, New Series, No. 87, University Extension Bulletin No. 8, Water Works Statistics of Thirty-eight Cities of Iowa, with the Meter Rates of Seventy Cities, by John H. Dunlap. 52 pages, 8vo. Iowa City, University, 1914.

The Water Power Problem in the United States, by Rome G. Brown. Reprinted from the *Yale Law Journal,* November, 1914. 33 pages, 8vo.

Harrison Safety Boiler Works, Cochrane Multiport Valves. 72 pages, illustrations, 8vo. Philadelphia, Harrison Safety Boiler Works, 1914.

American Pulley Company, Data Sheets. 36 pages, illustrations, 4to. Philadelphia, The American Pulley Company, 1914.

Protective Coating for Furnace Electrodes. (*Metallurgical and Chem. Engin.,* xii, 533.)—S. H. Fleming proposes to produce a coating of titanium nitride on furnace electrodes and other refractory materials. Titanium nitride is stable at high temperatures, is nonporous, tough, and hard, and otherwise possesses qualities that make it valuable as a protective coating for substances that are subjected to very high temperatures in an electric or other furnace. In order to form a coating a mixture of rutile and some binder is pressed on the article to be coated, which is then baked at a high temperature in the presence of nitrogen. Owing to the great affinity of Ti for nitrogen, the former is converted into nitride. A first coating of titanium carbide may be desired, as this substance wets carbon and enters the pores of its exterior surface and forms a perfect union with the carbon. This may be formed by applying a mix of titanium and carbon and heating with exclusion of air, forming titanium carbide. After the coating of carbide is formed the article may be heated in an atmosphere of nitrogen, thus converting part of the carbide into nitride. This latter conversion may be stopped before all of the carbide has been changed, if an inner coating of carbide is desired.

CURRENT TOPICS

The By-product Coking Industry. G. S. COOPER. (*Iron and Steel Inst.*, 1914.)—The Koppers combination oven can be operated as a gas oven with blast-furnace gas instead of with producer gas, and by consuming all available blast-furnace gases in this way a maximum amount of coke-oven gas becomes available in iron and steel works for heating open-hearth furnaces and for other purposes. The coal used for coking should not yield, on distillation, more than 7 to 8 per cent. water, reckoned on the dry coal. The coking character of Scotch coals deteriorates with exposure. The Koppers process for the direct recovery of ammonia from coke-oven gas has now been applied for the first time to coal gas at the Budapest gas works. The crude gas is cooled to 25° C., and delivered by an exhauster to the tar extractor. The gas is then reheated to 50° or 60° C. and treated with sulphuric acid in a closed saturator from which ammonium sulphate is removed continuously by an ejector working with steam or compressed air. The liquor from the cooler and tar-extractor is separated from tar and distilled with lime, the gases being delivered to the hot gas entering the saturator. The gas from the saturators is cooled and scrubbed with creosote oil for the recovery of benzene. The yield of benzene from coke-oven gas varies from 1 to 1½ gallons in South Wales to 2½ to 3 gallons per ton of coal carbonized in South Yorkshire, Derbyshire, the Midlands, and Cumberland. In open-hearth steel furnaces the durability of bulkheads and roofs is decreased by 8 to 10 per cent., and that of the chequer-work increased by 50 per cent., by the use of coke-oven gas. At Friedrich Wilhelmshütte the consumption of coal per ton of steel was reduced from 31.8 to 14.9 per cent.

Effect of Addition Agents in the Electro-deposition of Iron. O. P. WATTS and M. H. LI. (*Amer. Electrochem. Soc. Trans.*, XXV, 529.)—The electrolyte chosen as a basis for the addition of various substances consisted of 150 gm. of crystallized ferrous sulphate and 75 gm. of ferrous chloride ($FeCl_2, 4\,H_2O$) per litre, and had a specific gravity of 1.125 at 20° C. Ammonium sulphate (120 gm. per litre) gave good results as an addition agent; the sodium, magnesium, and aluminum sulphates were not satisfactory. Using the solution containing ammonium sulphate, the effect of 48 organic addition agents was tried; of these, only ammonium oxalate and hexamethylene tetramine improved the remarkably smooth and satisfactory deposit given by the original electrolyte. Solutions of ferrous ammonium fluosilicate or fluoborate are not satisfactory electrolytes.

Dissociation of Hydrogen into Atoms. I. LANGMUIR and G. M. J. MACKAY. (*J. of Amer. Chem. Soc.*, xxxvi, 1708.)—Evidence in favor of the view that at high temperatures hydrogen is dissociated into atoms is summarized as follows: The loss of heat from electrically-heated tungsten wires in nitrogen, mercury vapor, argon, and carbon monoxide varies with the temperature exactly in accordance with theory. In hydrogen, however, the loss of heat rapidly increases above 1900° K. (K. signifies absolute scale of temperature), and at 3500° K. is more than four times the calculated value; no secondary electrical effects capable of explaining the increase can be detected. At low pressures the loss of heat from tungsten wires is greater than at atmospheric pressure in hydrogen, but not in other gases. When a wire of tungsten, platinum, or palladium is heated above 1300° K. in hydrogen at a very low pressure (0.001 to 0.02 mm.) the hydrogen slowly disappears. It is not absorbed by the wire, but is deposited on the glass (sometimes in tubing a long distance from the bulb), especially when this is cooled by liquid air; ordinary hydrogen is liberated when the cooled portions are heated. The hydrogen which deposits in this way on glass is very active chemically, reacting with oxygen and phosphorus at the ordinary temperature. It is capable of diffusing through long tubes (at low pressures), and will then dissolve in platinum (at 50° C.), causing a marked increase in the electrical resistance of the metal and a corresponding decrease in its temperature-coefficient. The active hydrogen is not affected by an electrostatic field and therefore does not consist of hydrogen ions. Tungstic oxide, platinum oxide, and other substances contained in a tungsten filament lamp, together with hydrogen at very low pressure, are rapidly reduced when the filament is heated above 1700° K., although otherwise they are not affected by hydrogen.

Ammonium Sulphate Plant at Fushun, China. (*Board of Trade J.*, July 2, 1914.)—A Mond gas plant is being installed at the Fushun coal mines, in Manchuria, to supply power for use in generating electricity. This plant has been specially designed for the recovery of ammonium sulphate, Fushun coal being particularly suitable for this purpose, and it is estimated that 250 tons of coal will be gasified per day, and that there will be a daily yield of about 12 tons of sulphate. The intention is to sell this sulphate in Japan or California.

Transformations of Steels. H. DE NOLLY and L. VEYRET. (*Iron and Steel Inst.*, 1914.)—In the authors' view, the transformation-point is marked by the allotropic change of α- into β- or γ-iron, with a more or less complete dissociation of carbide and solution of the carbon liberated in γ-iron. If it be admitted that the allotropic change involves shrinkage, and that the dissociation and solution involve dilatation, this view is supported by the numerous dilatation curves given for steels of various composition.

The Kelp Industry. ANON. (*Report to the Board of Agriculture for Scotland on Home Industries in the Highlands and Islands*, 1914, 118.)—There has been a marked increase in the production of kelp since 1905, and the conditions are favorable for further extensions and developments, especially in respect to improved methods of collection and utilization, since the South American sodium nitrate deposits, from which four-fifths of the present supply of iodine is derived, are being gradually depleted. The Scottish sea-weeds are considerably richer in iodine than the giant kelps of the Pacific and the Japanese sea-weeds. Two methods of utilization of the algæ are available, the dry method of burning or carbonizing, and the wet method, although up to the present the latter has proved expensive in actual commercial working. In the United States a large company is now engaged in the manufacture of potassium salts from kelp on a commercial scale. The kelp is collected at sea by a boat fitted with a power-driven cutting device which can be lowered to about 8 feet below the keel. From the boat the kelp is delivered to an elevator and carried to a closed drier, in which it is kept in constant motion at not above 100° C. The drying should follow as soon after collection as possible, since the value of the sea-weed is reduced by exposure to the air. The dried weed is calcined at not above 400° C., in a brick kiln having a fire-clay lining and a cast-iron grate through which air enters. The volatile products pass to condensers through a tar chamber kept at a uniform temperature at the top and superheated at the bottom. The ash is treated for the recovery of potassium salts, iodine, etc. The products manufactured are: calcium, sodium and magnesium sulphates, potassium chloride, cyanide, chlorate and nitrate, sodium chloride, calcium carbonate, carbon, iodine, bromine, ivory black, varnish gum, creosote, alcohol, acetone, and combustible gas.

Effect of a Longitudinal Magnetic Field on Spark Potentials. R. F. EARHART. (*Phys. Rev.*, iv, Ser. ii, 135.)—The conclusions reached are that, using parallel plate electrodes, electric and magnetic fields parallel: (1) Spark potentials for pressures above the critical pressure are unaffected by the longitudinal magnetic field. (2) Those below the critical pressure are decreased by such a field. (3) When the pressure exceeds the critical value, the existence of the field requires a higher potential to maintain the discharge than if no field existed. (4) The variations noted in (3) are increased with increasing fields and become larger as the gas pressure is increased.

Electricity for the Household in Venezuela. ANON. (*Sci. Amer.*, cxi, No. 12, 223.)—The electric power company which supplies the city of Caracas, Venezuela, with electric light has recently installed day service, and hopes to educate the people to the use of electric stoves, irons, fans, etc. Electric heat and power are ideal for tropical countries. It may take some time to educate the Venezuelans to its advantages, but eventually it should prove indispensable.

A New Constant of Glass; the Cohesion-point. E. ZSCHIMMER. (*Silikat-zeits.*, ii, 129.)—When two clean, plane, polished glass surfaces are pressed together a firmly-adhering combination is obtained, in which, however, the surfaces are separated by an air layer at least 0.047 mm. thick, and a grayish-blue interference color is produced. The condition is merely one of *adhesion;* the intimate molecular contact of the glass which is the necessary condition for *cohesion* between the two surfaces is wanting. At high temperatures the adhesion slowly passes within a certain length of time into cohesion. The temperature required to cause this in a specified time is named the *cohesion-point.* It is a constant of the particular variety of glass, which relatively defines its specific softening properties, and allows the course of liquefaction to be exactly followed. It is, in fact, a substitute for the melting-point constant of crystalline substances. If cohesion-points are plotted against corresponding times of heating a representation of the softening of the heated glass is obtained. In practice 30 minutes may be adopted as the standard time of heating required to effect coherence of the surfaces. The glass, in the form of disks, 10 mm. diameter and 2 mm. thick, adhering in pairs, is heated in an electric tube furnace. The course of the coherence is easily followed; a black spot surrounded by Newton rings first appears, and gradually increases in size, eventually, at the completion of coherence, extending over the whole disk. The end-point is easily recognized. Numerous tables and curves are given showing the values of the constant for many varieties of glass.

Production of Steel Direct from Ore. E. HUMBERT and A. HETHEY. (*Iron and Steel Inst. Journ.*, lxxxix, 378–391.)—The authors have carried out experiments on the production of steel direct from the ore, as compared with the usual method of working with pig iron. Experiments were made in a normal Héroult electric furnace of 6 tons capacity, worked with single-phase current. Three series of tests were made, namely: (1) Direct reduction of siliceous Swedish iron ore. (2) Direct reduction of Swedish and a siliceous Swedish iron ore, with 30 per cent. of scrap mixed with the charge. (3) Direct reduction of Brazilian iron ore. Figures are given showing the composition of the charge, energy used, analyses, etc. It was found that good steel could be obtained without the carbon being above 0.4 per cent. at any time. The steel forged well and welded easily. The consumption of the electrodes was at the rate of 32 kg. per ton of steel. The wear of the lining was approximately the same as when melting scrap, but there was a good deal of ebullition, owing to the liberation of large volumes of oxide of carbon. The outstanding quality of steel by this process is its toughness. The authors claim that the steel is more free from harmful gases, such as nitrogen, by this process, and that the direct method has the advantages of simplicity, ability to use refractory and richer ores, freedom from impurities, cheapness, and efficient control of the quality of the steel.

A Powerful Magnet. A. COTTON. (*Electr. World,* lxiv, No. 11, 531.)—This article describes the work which has been so far done on the project of installing a powerful magnet at the University of Paris to permit experiments with fields of 100,000-gauss intensity. The University has granted $10,000 for the purpose. Weiss and Cotton have proposed the construction of a very large electromagnet of the Weiss type, weighing about 200,000 pounds. Deslandres and Perot have proposed the construction of various apparatus of smaller size of their own design. The commission is in favor of the first project. A review is given of the whole subject of electromagnet design. First he discusses electromagnets without iron core. He examines the form to be given to the coil and the method of winding, and the energy necessary to produce a certain field in the interior. He next discusses means of getting rid of the Joulean heat in the magnet winding. Then he takes up the design of an electromagnet with an iron core, and refers to the work of P. Weiss, who uses ferro-cobalt for the central part of the pole pieces, since in this way fields 10 per cent. higher than with pure iron can be obtained. He then discusses the problem how to proceed in enlarging a given electromagnet design to one of much larger dimensions. In the second part of the paper details are given of the electromagnet design of Deslandres and Perot and of Weiss's electromagnet with polar coils. A magnet such as is wanted by the University of Paris would cost $40,000, so that the available grant is not yet sufficient.

Effect of Titanium on the Magnetic Properties of Iron. K. P. APPLEGATE. (*Rensselaer Polytechnic Inst., Engin. and Science Series,* No. 5, 1914.)—To reduce hysteresis loss, iron is made magnetically softer by annealing or by the addition of foreign material. The addition of elements of low atomic weight, such as Si and Al, has been found to be particularly advantageous. Some of the effects of titanium are as follows: A decrease in hysteresis and an increase in permeability were obtained with Ti when less than 1 per cent. of that metal was used, an increase of hysteresis taking place with further increase of the metal. Prolonged annealing at 760° C. does not soften the material; since commercial Ti alloys cause deterioration in quality, the pure metal must be employed. Finally, titanium steels are not so good as the present standard silicon steels.

Spectrum of the Chromosphere. P. SALET and MILLOCHAN. (*Comptes Rendus,* clviii, 1000.)—Several photographs of the spectrum of the solar chromosphere have been made with the large spectrograph attached to the equatorial of the Paris Observatory, the solar limit being doubled by Condé interposing an Iceland spar rhomb. The chromospheric lines showed almost the same appearance in the two spectra, thus suggesting that the Stark effect due to a possible magnetic field is very feeble, if at all existent. It is hoped to test the method further by means of greater dispersion apparatus.

American Steel Rails. ANON. (*Eng.*, xcviii, No. 2541, 322.)—The production of steel rails in the United States last year was 3,502,789 tons. The corresponding production for each year of the decade ending with 1913 inclusive was:

Years.	Tons.	Years.	Tons.
1904	2,284,711	1909	3,023,845
1905	3,375,929	1910	3,636,031
1906	3,977,887	1911	2,822,790
1907	3,633,654	1912	3,327,915
1908	1,921,015	1913	3,502,789

The great extent of the American railroad network ensures a good annual demand for steel rails for renewals, but current American railroad construction does not exhibit the vigor and energy of former years, and it is significant that American railroad bonds to the aggregate amount of $578,673,000 are at present in default with respect to their interest.

Correction for Determining the Heating Value of Coal to be Applied on Account of the Oxidation of the Sulphur Compounds and of the Nitrogen in the Bomb Calorimeter. S. H. REGESTER. (*J. Ind. Eng. Chem.*, vi, 812.)—The results of the experiments indicate that the relative amounts of sulphur trioxide and dioxide in the bomb gases after combustion depend chiefly on the amount of nitrogen oxides formed in the bomb, which promote the formation of the trioxide just as in the manufacture of sulphuric acid by the chamber process; the ash of the fuel does not appear to exert any appreciable catalytic action. The formation of nitrogen oxides takes place much more readily from the nitrogen of the coal than from the nitrogen present in the bomb gases, and increases with increasing pressure and with the heat of combustion of the fuel. The usual correction applied to the heating value of a fuel, according to the sulphur content, based on the assumption that the sulphur is converted completely into sulphur trioxide in the calorimeter, is satisfactory in the case of coal with less than 2 per cent. sulphur, burnt in a bomb calorimeter from which the initial charge of air is not removed by rinsing out with oxygen; in the case of coals high in sulphur, a material amount of sulphur may be left as sulphide in the ash and as sulphur dioxide in the gas. If the air in the bomb be blown out with the oxygen of high purity, so that the concentration of nitrogen in the bomb is only a fraction of 1 per cent., then, with a fuel free from nitrogen, only a part of the sulphur will be converted into sulphur trioxide. With a non-nitrogenous fuel containing less than 0.08 gramme of sulphur in the sample burned, approximately quantitative formation of sulphur trioxide is obtained at 20 atmospheres pressure if the nitrogen concentration of the bomb gases be 6 per cent. The heat of combustion to SO_3 of the sulphur of pyrites was found to be about 4975 calories per gramme.

A New Process of Detinning. WALLACE SAVAGE. (*Brass World*, x, No. 11, 436.)—The inventor has discovered that at a temperature below 68° F., and preferably at 32° F., a coating of white tin can be changed to the non-adherent gray tin by the catalytic action of gray tin, applied in the form of a slimy mixture with a solution of tin ammonium chloride. A mixture of about 2500 pounds of gray tin is used with a solution of 10 pounds of tin ammonium chloride in 100 gallons of water. Agitation may be used, or the coated material may be merely moved through this slime.

Latest Developments in Wireless Telegraphy. H. BRAND. (*Verein Z. Beförd. des Gewerbefleisses, Verh.*, No. 4, 225.)—This monograph gives a useful *résumé* of the more recent developments in German wireless telegraph apparatus, a considerable amount of information being given regarding the use of the Telefunken type of wireless compass and of the station at Arkona, which uses this method for giving vessels their bearings in time of fog. The properties of the various types of directive antennæ are dealt with, and doubt is expressed as to the Marconi horizontal antenna giving an energy diagram differing much from a circle; tests at the Telegraphen-Versuchungsant did not, it is stated, show any lateral minimum at all. In any case, it is held that the fact that Glace Bay signals to Clifden are well heard at Buenos Ayres, more than twice as far from Glace Bay than Clifden is, and almost at right angles to the line Glace Bay–Clifden, renders it doubtful whether the antenna has any directive action whatever. The Telefunken compass makes use of the marked directive action of a pair of antennæ, oscillating in opposition of phase, as in the Bellini–Tosi arrangement, but, unlike the latter, requires a large number (8) of such pairs.

Development of Domestic Coal-tar Colors. I. F. STONE. (*Paper read before the New York Section of the American Chemical Society.*)—If the United States are to be independent of Germany, the intermediate products must be made on a large scale. This would require a protective duty sufficient to allow the business to be developed. The present duty of 10 per cent. was insufficient by reason of the convention which controlled the manufacture in Germany, and immediately reduced the price by an equivalent amount. This had happened in the case of aniline oil, the manufacture of which was begun about three years ago by the Schoellkopf Aniline Works at Buffalo, and which now furnished about one-quarter of the consumption of the United States, taking oil and salts as one product. The unfair competition of Germany could be readily checked if the Government would incorporate in its tariff what was known as the "dumping" clause which forbids the importation into and the selling in the United States of any products at a less price than they are sold in the country where they are produced. The Schoellkopf factory produced aniline oil thirty years ago, but had to abandon it on account of being unable to obtain benzol. That was no longer a diffi-

culty; moreover, by-product coke ovens could readily be established to increase the supply. There was also the manufacture of explosives to increase the consumption of intermediate products. No government could afford to be dependent on a foreign supply of such bodies as trinitrololuol and carbolic acid. In self-defence it must create some sort of tariff or subsidy to protect the industry. Dr. Hesse had stated that, out of 900 dyes, 76 were made in the United States. The real number was about 100, and when it was remembered that many of the 900 were defective or obsolete, the proportion was larger than appeared on the surface. They could satisfy 90 per cent. of United States color demands, referring to types not quantities, the remaining 10 per cent. being mainly alizarin and indigo. The amount of dyestuffs imported into the United States of America in 1913 was: Aniline dyes, $7,000,000; indigo, $1,000,000; alizarins, $1,500,000. These were cost prices, and when the United States duty of 30 per cent. and the expenses were added, it meant the Americans were paying about $12,000,000 for their supplies, not including the home manufacture, which might be $2,000,000 more. The author then combated some statements of the *Scientific American* in regard to a protective tariff, and considered that a higher tariff would stimulate production and competition, and that competition would always control the price. Indigo and alizarin were not made in America and there was no duty on them, yet customers had to pay more for them, because their prices were controlled by a combination.

Direct cotton black was made in America, and there was a 30 per cent. import duty on it. In consequence, the Europeans had been compelled to reduce their selling prices in America to less than they were charging their customers in Europe. The author also demanded a revision of the United States patent laws on the lines of the recent British Amendments. In 1909 this was proposed, but Germany negotiated a treaty by which the German working clause was made inoperative on American inventions. Whether this was beneficial was a question, but it certainly did not benefit the United States coal-tar industry. From 1880 to 1883, when there was an import duty of 35 per cent. ad valorem and 50 cents per pound specific, there were ten dye factories in the United States. In 1883 the specific duty of 50 cents was abolished, and within one year five of these factories succumbed, and now only four were left, and these had a great struggle to maintain themselves.

The change in the patent laws was of less importance in the case of colors than in other lines, as there were quite enough dyes on which the patents had expired to constitute a large industry.

America could manufacture dyes if it were made commercially possible, but whenever conditions became normal, without protection, they would have to give up the manufacture of intermediate products, because they could get them cheaper in Europe than they could make them.

Modifications of a Balance for Ease and Quickness of Weighing. G. A. SHAKESPEAR. (*Phil. Mag.*, xxvii, 990.)—In the use of a good physical balance the accuracy of weighing is mainly limited by (*a*) the accuracy of the weights, (*b*) constancy of temperature in the balance case, (*c*) the accuracy with which the position of the rider can be read, and (*d*) the magnitude of the smallest measurable deflection of the beam. Frequently, details (*a*) and (*b*) are not sufficiently regarded. Theoretically, the sensitiveness may be increased so that the smallest appreciable change of position of the rider produces an observable deflection of the beam. In practice, however, it is found advisable to have a degree of sensitiveness for which a comparatively large change of position of the centigramme rider produces no appreciable change in deflection. In other words, the rider is usually too small and the means of measuring deflection not sufficiently delicate. In the balance described the rider is, therefore, comparatively large (either 0.5 or 0.05 Gm.), and the deflection is observed optically by using a concave mirror attached to the beam. The rider beam runs from end to end of the beam, the upper edge being in the plane of the knife-edges. It is divided into ten equal divisions, each of which is divided into ten smaller divisions. The rider is in the form of an elongated ring which surrounds the rider beam, and is provided with a hook at its upper part. The rider is moved by a thin silk cord passing through a slit at each end of the balance case. The effect of using the concave mirror is to provide a pointer of considerable length, but with small mass and moment of inertia, so that the period of oscillation is appreciably reduced. There is, moreover, no parallax. The weights are placed in the right-hand pan, the rider being on the zero mark at the left-hand end of the beam.

Utilization of Gases in Iron Works. K. RUMMEL. (*Zeitschr. Vereines Deutsch. Ing.*, 58, 1153–1160.)—The author reviews present-day applications of coke-oven and blast-furnace gases in iron works; points out the difficulty of predetermining efficiency, and discusses the thermal efficiency and economic aspects of gas utilization in boiler firing, gas engines, regenerative and other ovens, under various conditions. Owing to the importance of the latter it is impossible usefully to abstract the quantitative data given. Capital cost, load factor, and working costs are taken into consideration. The best means of utilizing available gases must be considered with reference to the special circumstances of each installation. The coke oven or blast furnace providing the gas should be considered as an independent concern, wishing to sell gas as dearly as possible. Gas should be used in those applications which will stand the highest charge per 1000 cubic feet. A table is presented showing the actual "value ratio" of purified coke-oven and blast furnace gas of the same thermal value as coal; this ratio varies from 1.0 to 1.45 and is 2.5 : 1 for coke-oven gas as compared with lighting gas. From examples and general con-

siderations in the original it appears that blast-furnace gases are best used in power applications; for the production of blast-furnace draught, for current generation, and, finally, in steel works gas blasts.

Next in the descending scale of advantage comes gas firing in steel works and rolling mills, in Martin ovens, soaking pits, and drying ovens, etc. Gas should be used below steam boilers only as a last resort. On this basis gas-engine plant is preferable to steam turbines, whether the latter be supplied from gas- or coal-fired boilers. Allowing, however, for the difference between gas supply and demand, there is still very useful application for steam plant. Surplus gas supply is best used beneath boilers which are also arranged for coal firing. Steam so produced finds advantageous application in rolling-mill drive, and frequently yields higher overall efficiency than is obtainable from any other equipment. From special cost investigations the author concludes that steam drive is frequently preferable to electric motor drive in heavy rolling mills.

Potash from Felspar and Other Sources. ANON (*Chem. News*, CX, 175.)—In view of the stoppage of supplies of potassium salts from Germany, attention is directed to a process developed by Ward and Wynants (English Patent 3185, December 30, 1857) for the extraction of potassium salts from felspar, which gave satisfactory results. Felspar ground to the fineness of Portland cement was mixed with powdered fluorspar or other fluoride, the fluorine being calculated equivalent to the alkali in the rock. A mixture of chalk and lime was then mixed with the materials so that the proportion of Ca was double that of the SiO_2 and one and a half times that of the Al. On the large scale it was found preferable to use about 10 per cent. excess of lime. The mixture was made into cakes and heated to a yellowish red for a few hours. The porous frit obtained was lixiviated with boiling water, which extracted 90 per cent. of the potash originally present in the rock in the form of hydroxide and carbonate. The residue might be worked up into hydraulic cement by removing the fluorine. Another possible source of potash is the spent wash from the fermentation of molasses from the beet-sugar industry. The wash, neutralized by chalk, is decanted, evaporated, and calcined. The crude ash contains about 50 per cent. of potassium salts. The kelp industry is another source of potash, with the advantage of also yielding iodine.

Fire Clay in Coal Mines. J. W. MELLOR. (*Times. Eng. Suppl.*, Sept. 25, 1914.)—A small number of samples of clay from North Staffordshire coal mines have been tested with satisfactory results, and it is suggested that a valuable source of fire clay is being overlooked. One sample collapsed only at the same temperature as Seger cone No. 33; a good British fire clay collapses at cone No. 30 or 31—*i.e.*, at a lower temperature.

The Nickel-plating of Aluminum. E. TASSILY. (*Rev. de Métallurgie,* xi, 670–673.)—None of the large number of the methods which have been patented for nickel-plating aluminum appears to give satisfaction in practice. Generally, the nickel is deposited on an intermediate coat of copper, zinc, or iron, but even then the adherence leaves much to be desired. A method recently patented by Carnac permits the direct deposition of an adherent coating of nickel which can be polished, will stand hammering and heating, and, in fact, the result behaves so much like an alloy that the author has been led to call it aluminum-nickel. The method consists in passing the metal through a bath of boiling potash, brushing with milk of lime, soaking for some minutes in a 0.2 per cent. potassium cyanide solution, and, finally, treating in a bath of 500 gm. HCl, 500 gm. water, and 1 gm. of iron until the Al assumes a mottled metallic appearance. After each operation the metal is well washed in water. Nickelling is carried out in the ordinary way in a bath containing 50 gm. nickel chloride, 20 gm. boric acid, and 1000 c.cm. of water, using a current at 2.5 volts and a density of 1 amp./dm.^{2} The success of the process appears to depend on the thorough cleaning and the fact that a thin layer of iron is deposited on the Al from the ferruginous bath. That there is a layer of iron on the metal is proved by the fact that on testing by means of the magnetic balance the susceptibility of metal which has been through this bath is 14 times as great as that of the metal which has simply been boiled in potash. Microscopic examination of the surface reveals the presence of small cells in which the Ni is deposited during electrolysis, the process being assisted by the formation of numerous small couples. The resulting product resists the action of moist air, hot and cold acids and alkalies, hot concentrated salt solutions, alcohol, and does not permit the sweating of petrol. Compared with pure Al, the tensile strength is increased, the coefficient of expansion decreased, while the density is only slightly increased. It can be applied in railway construction, shipping, the manufacture of instruments, cooking utensils, and so on.

Fuel Saving through Proper Dimensioning of Steam Piping. GILLEAUME. (*Feuerungstechnik,* vol. xi, No. 14.)—This article argues that fuel can be saved by using higher steam velocities in pipes; the limit for safety with reciprocating engines is 82 to 98 feet per second. The Berlin Electricity Works Company carried out experiments and obtained considerable saving in fuel by eliminating pipes which had been put in to reduce the fall of pressure. Formulæ are discussed with the results of experiments.

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